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ANÆSTHESIA AND ANÆSTHETICS

GENERAL AND LOCAL

FOR PRACTITIONERS AND STUDENTS
OF MEDICINE AND DENTISTRY

BY

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PREFACE.

This book is not intended as a treatise on anæsthesia, or anæsthetics, its limitations being too pronounced. Neither has it anything original to set forth. Its production was impelled rather from the want of a work on this subject sufficiently concise to fit the opportunities of the average student or busy practitioner, yet complete enough to afford a fair and impartial resumé of our present knowledge of this important subject.

The rather extensive literature of the past decade on the subject of anæsthesia attests a growing realization of the importance of more accurate knowledge of anæsthetics and their administration. The growing tendency to relegate the administration of anæsthetics to those who are more or less expert in their administration is even now extending beyond hospital service and into private practice, and the necessity in our medical colleges of both instruction and practice in the administration of anæsthetics is being recognized. Instead of regarding the anæsthetist as the least important factor in the successful outcome of a surgical procedure, it is understood that in some instances, at least, his may be a responsibility equal to, if not greater than, that of the operator himself. In other words, many of the accidents and complications of, and sequences to, the administration of anæsthetics may be avoided by intelligent and skillful administration.

Credit is given in the text to those whose authority has been abstracted. It remains only for the author to acknowledge the courtesy of Dr. Elgin MaWhinny, of the Northwestern Dental School, who has written the chapter on Local Anæsthetics in Dentistry; and that of Dr. L. L. Skelton, professor of physiology in the Chicago College of Dentistry, for revising and offering suggestions to the chapter on the physiology of anæsthesia.

J. M. P.

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PART I.

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CHAPTER I.

HISTORICAL.

Three achievements stand out in the records of the last century which for the direct mitigation of human ills and indirect influence upon the advancement of medical science have no parallels in the history of medicine. It is hardly necessary to say that these achievements are vaccination, anæsthesia, and antisepsis.

Anæsthesia is the term that was given by Dr. Oliver Wendell Holmes to denominate that lethargic state which had from time immemorial been at once the hope and the despair of medical savants, and the successful induction of which he apostrophized as follows: "Nature herself is working out the primal curse which doomed the tenderest of her creatures to the sharpest of her trials; but the fierce extremity of suffering has been steeped in the waters of forgetfulness, and the deepest furrow in the knotted brow of agony has been smoothed forever." This Death of Pain, this medical will-o'-the-wisp, had for centuries eluded the grasp of medical investigators ever since the Great Physician "caused a deep sleep to fall upon Adam; and he slept; and he took one of his ribs and closed up the flesh instead thereof."

The anticipation of a pain-destroying agent was a medical dream, older, more persistently pursued, and more enticing than the fancies of the fabled lotus-eaters. No other possibility in medicine ever held forth such allurement to the surgical patient, of whose feelings on the approach of the surgeon Tennyson wrote, "Sent a chill to my heart when I saw him come in at the door."

The belief in and the search after some agent by which pain might be annihilated is as old as medicine itself. The fact that though the ancients employed various devices to annul pain the eighteenth century was not marked by any advance in this direction, notwithstanding its eminent medical men, has been a subject of comment. The atmosphere of mysticism, charms, incantations and charlatanism that surrounded the early history of

pain-destroying agents tended to discredit the whole matter, and in part, at least, explains why the age that produced Sydenham and Paré was barren in this respect. Then too, must be taken into consideration the religious ideas, based on the primeval curse, which were prevalent at that time and against which Simpson waged such an energetic and convincing campaign.

In Homer's Odyssey there is reference to a drug used by Helen as a nepenthe or narcotic, "a drug to lull all pain and anger and bring forgetfulness of every sorrow." The nature of the nepenthe of Helen which "Immediately she (Helen) dropped into the wine of which they drank," is unknown, but it is believed by some to have been opium. Dioscorides and Pliny, about the beginning of the Christian era, described the Memphis stone which gave forth soporific fumes. The former describes the use of a decoction of the root of the *Atropa Mandagora* in wine: "And some making decoctions in wine of the roots to a third, this being strained is put past. Using one wine-glassful in the case of the sleepless and those suffering excessive pain, and in the case of those on whom they wish to produce insensibility when cut or burnt." Dioscorides further describes the hypnotic effects of mandrake roots on shepherds, and the analgesic properties of the decoction as used by physicians. This drug, according to Theodoric, when mixed with other narcotics and inhaled caused a deep sleep from which the patient could only be aroused by the fumes of vinegar. The Romans used mandrake to stupefy criminals at the time of crucifixion, though probably the material used was a compound of several drugs. Mandrake was used as a surgical anæsthetic down to the thirteenth century, and its employment is mentioned by Galen. Lucian makes several references to mandagora: "But do you think he has been so dosed with mandagora as to hear those things, and not to know?"—"*Adversus Inductum*," 23; "You sleep as if through mandagora." —"*Timon*," 2.

According to Foy, the schools both of the Eastern and Western Califates were familiar with and employed mandagora. Its properties were described by Avicenna, Averhoes, Paulus, Aëtius, Isodorus, Serapion, Celsus, and others. They employed it as a hypnotic and analgesic in various ways. Mandrake has been used to relieve the pains of labor, and Dr. Sylvester suggested

that it was for such a purpose that Rachel begged the mandrake from Ruben.

In the third century a Chinese surgeon Hoa-tho, is said to have employed some sort of anæsthetic drug, and in the thirteenth century da Lucca, a Tuscan surgeon, employed an oil by inhalation. The Assyrians compressed the vessels of the neck by a band before practicing circumcision.

With the introduction into Europe, by the Moslems, of the process of distillation, we find the employment of volatile preparations for the purpose of relieving pain. Giabattista Porta (1589), a surgeon of Naples, tells of volatile drugs,—an essence of hyoscyamus, solanum, poppy, and belladonna, kept in leaden vessels—which drugs produced sleep upon inhalation: "Thereby he would be buried in a most profound slumber, nor be aware of what had been done to him." Vigo tells of producing insensibility by "smelling of a sponge wherein opium is." Theodorico, son of Ugone da Lucca (born in the middle of the twelfth century), tells of an oil *de lateribus* prepared and used by his father, which by inhalation alone put patients asleep on occasions of painful operations. He further describes the substance used with the somniferous sponge of da Lucca as consisting of opium, mulberry juice, hyoscyamus, mandagora, wood ivy, lettuce seeds, dock seeds, and water hemlock. In this mixture a sponge is boiled. For use it was soaked in hot water and applied to the nostrils. A sponge dipped in vinegar was applied to the nostrils to awaken the patient, or the juice of the root of fenngrek was thrown into the nostrils.

The principle of the inhalation of volatile substances is very ancient. Aphrodite threw herself on a bed of lettuce in order to mitigate her grief for the death of Adonis.

Indian hemp is an old remedy for pain, and was used to stupefy criminals. Herodotus mentions a custom of the Scythians of inhaling the fumes of a certain kind of hemp. Indian hemp was used as an analgesic even earlier than mandrake. M. Julien laid before the French Academy of Medicine a manuscript called Ko-Kin-i-ting which contained the information that Ho-tho gave a preparation of hemp (ma-yo) to patients, who became insensible as if "drunk, or deprived of life," and who, when revived, had not felt the slightest pain during the operation.

The name "haschish," by which Indian hemp was known in the Orient, is said to have given rise to the term assassin (literally, eater of haschish) because an Arab Sheikh fed the drug to his followers in order to produce delightful sensations which he induced them to believe he could obtain for them eternally if they would carry out his bloodthirsty designs. Simpson thought the nepenthe of Homer was a species of Indian hemp.

Reference to the poetry of the sixteenth and seventeenth centuries shows that drugs of this nature were well known at that period. Thus: "Bringeth his patient in a senseless slumber,"—Du Bartas; also, "Will stupefy and dull the sense awhile." . . . . "locking up the spirits a time."—Shakespeare. Chumappe (1534) alludes to the use of soporific preparations at that period, Boerhaave's anæsthetic powder is said to have consisted of oil of cinnamon, oil of cloves, citron peel, sugar, red coral, and opium. A dose was given one hour before operation, and another one-quarter of an hour before if necessary. Brooke (1562), from whom Shakespeare was supposed to have derived much inspiration for his "Romeo and Juliet" (1597), in his "Tragical Historye of Romeus and Julietta," etc., describes friar Laurence as a great searcher of nature's secrets and a maker of "divers soporiferous simples" which would bring the "receiver into such a sleepe and burieth so deeply the senses and other spirits of life, that the cunningest Phistian will judge the party dead." Also, "When the operation is perfect and done hee returneth into his first estate."

Marlowe, in *The Jew of Malta,* refers to the mandagora thus:

"I drank of poppy and cold mandrake juice,
And being asleep, belike they thought me dead,
And threw me o'er the walls."

Even as late as Mrs. Browning we have the following:
"Have the pigmies made you drunken
Bathing in mandagora?"

In the early part of the seventeenth century Valverdi, an Italian, practised compression of the vessels of the neck in order to produce unconsciousness, a procedure undertaken by the ancient Assyrians at the time of circumcision. Compression of the vagi, of the limb to be operated on, of the nerve supplying the

part to be operated on, have all been recommended and practised. Dorsey, Mott, Norris, and others tell of their more or less successful use of opium or whisky, or both, to produce some greater or less degree of insensibility to pain during operations.

Hypnotism was known to the ancient Egyptians, Persians, and Indians, and it is thought by some that they may have used it for the purposes of surgical anæsthesia. Simpson quotes the lines of Middleton (1617):

"I'll imitate the pities of old surgeons
To this lost limb—who ere they show their art
Cast me asleep, then cut the diseased part."

Greatrakes (1661), by means of passes over the subject's body produced a magnetic sleep. Greatrakes was a celebrated Irish "stroker" who was called to England tc treat Lady Conway, of Warwickshire. He obtained considerable notoriety.

In 1766 Anthony Mesmer appeared with his theory of "Animal Magnetism." In 1839 a Frenchman named Potet introduced hypnotism into London under the name of mesmerism. He was supported by Dr. John Elliotson of the University College Hospital, who was subsequently ruined because of his advocacy of mesmerism. The British physicians, Simpson, Liston, Braid, and Edsaile, of Calcutta, were more or less successful in experimenting with hypnotism. Edsaile is said to have employed hypnotism in connection with rather severe surgical operations. The ancient Greek physicians must have recognized the principle of hypnotism, for in the Greek Anthology we have: "Touching them with his hands he (the physician) quickly makes them whole."

Although sulphuric ether was discovered by Valerius Cordus in the year 1540 (though by some its discovery is attributed to the Arabian chemist Djafar Yeber), hydrogen by Cavendish in 1766, nitrogen by Rutherford in 1772, oxygen by Priestly in 1774, and nitrous oxide by Priestly in 1772 or 1776, it was not until the close of the eighteenth century that these gases began to be employed in any manner likely to lead to the discovery of their anæsthetic properties. The inhalation of ether for the relief of asthma was recommended by Pearson, of Birmingham, in 1795. Beddoes organized a "Pneumatic Institute" at Clifton in 1798 for

the treatment of pulmonary diseases by the inhalation of gaseous and vaporized medicaments. Thornton and others also employed like medication about the same period. In 1799 or 1800 Mr. Humphrey Davy, then an assistant of Dr. Beddoes, discovered by personal experiment that nitrous oxide gas would relieve toothache and other pains, and suggested its use for the production of anæsthesia. He described its effects as "uneasiness being swallowed up for a few minutes by pleasure." Although he does not appear to have carried its administration far enough to produce unconsciousness, he nevertheless recognized the possibilities of nitrous oxide gas in this direction, and recommended its employment in "surgical operations in which no great effusion of blood takes place."

In the early part of the past century the effect of nitrous oxide gas was known to many, and the gas was inhaled for diversion by the students of the University of Pennsylvania. "Ether frolics" were an amusement of the time among young people.

In 1818 Faraday pointed out that ether when inhaled had effects similar to laughing gas, as the following from the *English Quarterly Journal of Science and Arts,* which is attributed to him, shows: "When the vapor of ether mixed with common air is inhaled it produces effects very similar to those occasioned by nitrous oxide. . . . By the imprudent inspiration of ether a gentleman was thrown into a very lethargic state, which continued with occasional periods of intermission for more than thirty hours."

In October, 1888, Dr. O. P. Hubbard read a paper before the New York State Medical Association, in which he detailed the circumstances of the administration of nitrous oxide gas to his brother and others at Rome, Oneida county, N. Y., in November, 1821. During one of the exhibitions a young man was found in an adjoining room lying completely unconscious beside the gasometer. He was removed and soon recovered from the unconscious state."

Pereiras' work on Materia Medica (1839), described the anæsthetic properties of ether when inhaled, and in 1842 Dr. Crawford W. Long, of Georgia, who is said to have learned from a negro servant named Wichita that complete unconsciousness had resulted some time previously in a negro lad whom his companions

had forcibly compelled to inhale some ether, employed ether while removing a tumor. He had used it for the relief of pain, and subsequently to this operation he repeated his experiments, and demonstrated the use of ether to his brother physicians. He appears to have been conservative in his exploitation of the use of ether, and while directly in the line of success the world at large was not made to recognize this until after he was forestalled by Morton in the practical application of ether as a general surgical anæsthetic. Dr. Long is regarded by many, especially in the Southern States, as the discoverer of anæsthesia. (A statue of Dr. Long is to be placed in a hall at Washington, D. C., reserved for the statues of two distinguished men from each State. The statue is a memorial from the physicians of the State of Georgia.)

In December, 1844, Dr. Horace Wells, a dentist of Hartford, Conn., observed while attending a popular lecture given by a Mr. Colton, a chemist, that a Mr. Cooley while under the influence of laughing gas struck and injured his limb without suffering any pain. He at once experimented upon himself, and submitted to the extraction of an aching tooth, at the hands of a colleague named Rigg, while under the influence of nitrous oxide gas. He successfully repeated the experiment upon others, and instituted what he called a "new era in tooth-pulling."

In company with a former pupil, W. T. G. Morton, he attempted to give a demonstration in Boston in 1844. The attempt failed, according to Wells, because of the premature withdrawal of the gas. The crowd of practitioners and students present were frank and unrestrained in their expressions of disappointment, and the disappointment resulting from this failure induced an illness from which Wells never recovered. He explained his discovery before the French Academy of Sciences in 1846, and died in New York, in 1848. It is said he opened a vein while in his bath.

William Thomas Green Morton was born in Massachusetts, studied dentistry in Baltimore, and was a successful practitioner in Boston. He experimented with drugs and with hypnotism in connection with the painless extraction of teeth, and as we have seen was associated with Wells in his investigations of nitrous oxide gas. After the failure of the experiment of Wells he abandoned gas and tried chloric ether with unsatisfactory re-

sults. At the suggestion of his preceptor Dr. Charles Jackson—Morton being at that time a student of medicine—a physician of Boston, but best known as a geologist and chemist, he experimented with sulphuric ether, beginning his experiments on animals. His success in this direction encouraged him to make a personal experiment, and in September, 1846, he inhaled ether from a handkerchief while sitting in his operating chair. He was unconscious for several minutes, and on regaining consciousness he was so elated by his success that he decided to again inhale the drug and submit to an extraction while under its influence. At this moment the door bell rang and he admitted a man named Eben Frost whose face was bandaged and who was in that state of mingled hope and consternation so familiar to all dental surgeons. He asked if it were not possible to mesmerize him, and readily consented to inhale ether when assured that it was superior to mesmerism. To the joy of the operator and the astonishment of the patient the attempt was perfectly successful, and thus was accomplished the first operation under ether anæsthesia.

Morton then proceeded to obtain an opportunity for the public demonstration of the practicability of anæsthesia. This was furnished him in the surgical amphitheater of the Massachusetts General Hospital in Boston, on October 16, 1846, where the unsuccessful demonstration by Wells had taken place two years before. The surgeon in charge was Dr. John C. Warren, to whom great credit is due for placing the opportunity in Morton's hands in spite of the previous failure in this direction. The operation was the removal of a vascular tumor from the left side of the neck of a young man who was described in the records as "Gilbert Abbott, aged twenty, single, painter." The Harvard Medical class was present, also several prominent physicians and surgeons. The exhibition of the anæesthetic was a complete success, so much so that Dr. Warren turned to those present and said, "Gentlemen, this is no humbug."

The fame of the wonderful new agent and of its discoverer spread rapidly, and then came Dr. Jackson, jealous of the fame of Morton and anxious to participate in the benefits of the discovery, with a claim as to the rights of discovery, basing his claim on the assertion that he had been aware of the power of

ether since 1842. He had suggested the drug to Morton, and undoubtedly had advised him as to its nature and the best methods of administration, but beyond this his claim was groundless. And here Morton made the mistake of his life,—an attempt to patent the agent under the name "letheon" and to keep its nature secret. As he was not a graduate in medicine he was not technically bound to observe that rule of medical ethics which from the beginning of medicine has forbidden the adoption of such a course in relation to matters which are of benefit to common humanity, yet how different might have been the result to himself if he had held himself bound by this rule, the breaking of which forfeited him the esteem and sympathy of the medical public which would have been of incalculable value in the controversy which followed.

Morton was anxious to silence Jackson as to the nature of ether which he had attempted the impossible task of disguising with aromatics, and to this end he recognized the rights of Jackson in his application for letters patent. Jackson, dissatisfied with his share of the bargain, attempted to pose at the sole discoverer, and thus arose an acrimonious controversy which continued long after the death of Jackson in an asylum. The matter was subsequently investigated by a Congressional committee whose report substantiated the claims of Morton.

Morton's attempt at secrecy was unavailing. The world at large knew that "letheon" was simply ether. Dr. Bigelow soon became aware of its nature and spread the news in England. The public disregarded the patent proceedings. Indeed the government representatives in the army and navy ignored the effort to secure patent papers, and an attempt to secure a grant of $100,000 to Morton from the government failed largely through the antagonism of Jackson supported by the connection of his name with the patent papers. A testimonial of $50,000 from England also failed because of the doubt arising through the same influences, while a French prize was divided equally between Morton and Jackson.

Morton's life was clouded by a feeling of resentment against the public whose position he mistook for ingratitude. Such honors as he received did not obviate the ill health largely due to the bickerings which continued over the rights of discovery, and

which resulted in his death in 1868. To-day Morton is generally regarded, and his memory is honored, as the true discoverer of the practicability of ether as an anæsthetic. Had he followed the example of the other great discoverers in the field of medicine he would have had as little cause for complaint.

Upon a monument erected by the citizens of Boston over the grave of Morton is the following inscription:

William T. G. Morton,
Inventor and revealer of anæsthetic inhalation,
By whom pain in surgery was averted and annulled;
Before whom in all time surgery was agony,
Since whom science has control of pain.

No medical discovery was ever more readily adopted than the use of anæsthesia. It was at once taken up in England, and surgical operations were performed under its use by Dr. Boot and by Liston in December, 1846. Dr. J. Y. Simpson immediately adopted ether in obstetric practice. He soon discovered the difficulties which attend its administration and which were not so avoidable then as now, and began experimenting in order to find a better agent. The unpleasant odor which ether gave to his clothes also induced Simpson to try other agents. He wrote: "I found that no busy obstetric practitioner could extensively employ sulphuric ether without inevitably carrying about with him, and upon his clothes, an odor so disagreeable to many other patients and other houses, as to make his presence there aught but desirable." Himself and his assistants, Drs. Keith and Duncan, inhaled various substances experimentally. Mr. Waldie, a chemist of Liverpool, suggested to Simpson that chloroform, a constituent of "chloric ether," might be tried with benefit. Chloric ether was at that time used as a carminative, and consisted of chloroform and rectified spirit. Mr. Waldie, in an article on the "Medicinal History of Chloroform" (1847), states that as far as he knows chloroform was introduced into England about 1838. A prescription was presented at Apothecaries Hall, Colquitt street, Liverpool, for filling, one ingredient was chloric ether which was unknown there. The chemist found the formula for chloric ether in the United States Dispensatory, and prepared some. The prop-

erties of chloric ether pleased Dr. Formby, who introduced it into Liverpool practice. Waldie states that while he was in Scotland, in October (1847), Simpson asked him regarding some agent that would answer his purpose, and Waldie suggested chloric ether, promising to prepare some on his return to Liverpool and send it to Simpson. He was delayed, however, and in the meantime Simpson procured some in Edinburgh.

Attempts to anæsthetize with chloric ether had failed. Chloroform was described as a "curious liquid" discovered almost simultaneously by Guthrie, Soubeiran, and Leibig in 1831, and chemically described by Dumas in 1835. In March, 1837, Flourens, the French chemist, described the effects of chloroform on animals. Guthrie, of Brimfield, Mass., then residing at Sackett's Harbor, N. Y., obtained what is now known as chloroform, though he supposed he had discovered an easy and cheap process of making what was known as "Dutch liquid," a preparation of the Dutch chemists, or ethane dichloride, which greatly resembled the substance discovered by Guthrie. He therefore used the term chloric ether in referring to the preparation which he had discovered. Guthrie is said to have noticed in the American Journal of Science and Art a statement by a correspondent to the effect that a mixture of alcohol and chloride of olefiant gas (then recently discovered) was an agreeable and diffusible stimulant. This led to his experiments, and in May, 1831, he sent to Mr. Sillman, the editor of the Journal mentioned, an article entitled, "A Spiritous Solution of Chloric Ether," which was published in October, 1831. A later and more complete account describing his method was published in January, 1832, and is referred to by Pereira (Pharmaceutical Journal). Soubeiran's account was published in January, 1832. Leibig's account was published in November, 1831 (Foy), or not until 1832 (Pereira).

Samuel Guthrie was born in 1782, was a surgeon in the U. S. Army in 1812, and died in 1848, just as the fame of chloroform as an anæsthetic became widespread. The recognition of his position as the discoverer of chloroform is largely due to the Chicago Medical Society, and recognition as such has at last been accorded him by his brethren of the Jefferson county, New York, Historical Society.

In Sillman's Journal, of January, 1832, is related an instance

of the use of chloroform by inhalation by Prof. Ives, of Yale College. It was also used by Dr. Nathan B. Ives for asthma, cough, quinsy, etc.

Simpson determined to try chloroform, and did so on the fourth of November, 1847, with the result that himself and co-experimenters awoke from temporary unconsciousness to find themselves upon the floor, under under the table. Simpson read a paper before the Medico-Chirurgical Society, on November 10th, detailing cases in which he had already used the anæsthetic successfully, and by the 15th of November he had administered chloroform to about fifty individuals without any bad results. In 1870, Simpson, in a letter to Dr. Jacob Bigelow, of Boston, stated that "the first case of an anæsthetic operation under chloroform occurred in Edinburg on the 15th of November, 1847." The first operation under ether in England is said to have been the extraction of some teeth by a dentist, a Mr. Robertson, of London, in 1846, at the request of Dr. Boot.

Simpson regarded chloroform as "more portable, more manageable and powerful, more agreeable to inhale, and less exciting" than ether, and an agent giving greater "control and command over the superinduction of the anæsthetic state." For years Simpson fought an earnest and persistent fight against medical conservatism, religious bigotry, and confused public opinion. And the rapid introduction of the use of anæsthetics in Great Britian is largely due to his successful advocacy of its cause. In none of the writings or public utterances of Simpson is there to be found any acknowledgment of the credit due to Guthrie or Ives for the discovery or employment of chloroform.

Chloroform, which at first was regarded as an anæsthetic without danger, became almost the sole anæsthetic agent in use in Great Britain and the Continent. In the United States ether held its own as a safe and reliable agent for general surgical anæsthesia. Occasional deaths under chloroform and the seeming inexplicable cause of these fatalities brought about a realization of the dangers of chloroform as an anæsthetic, as well as a state of doubt and confusion as to which agent was the better.

In 1858 Snow published a work on chloroform and other anæsthetics in which he claimed that chloroform fatalities are generally due to primary cardiac paralysis from the inhalation of

too concentrated vapor. Though subsequent investigations tend to prove that there is some primary interference with respiration, the conclusions of Snow are by many regarded as correct.

Clover, who published an account of his chloroform inhaler in 1862, experimented with both chloroform and ether with the conclusion that ether was the safer drug. In 1864 the Royal Medical and Chirurgical Society appointed a committee to investigate chloroform, which reported in favor of Snow's conclusions, and recommended a mixture of alcohol, chloroform and ether which was originally proposed by Dr. Geo. Harley, and was known as the A. C. E. mixture. Claude Bernard, Richardson and others investigated the question, and in 1867 Richardson introduced bichloride of methylene, which as an anæsthetic had a short life. The same year saw the Junker inhaler for chloroform, which proved of special value in surgery of the mouth, throat, and nose.

About this time Colton, the lecturer who gave Wells his inspiration regarding nitrous oxide gas, revived the interest in this gas. He had formed an association in New York for performing dental work with the use of gas, and his reports stimulated the interest of dental surgeons. He visited Paris in 1867 and gave demonstrations before Dr. Evans, the well known exponent there of modern dentistry. Dr. Evans demonstrated the use of gas in London in 1868, and the Odontological Society then issued a very favorable report on the use of the gas about eight months later. Nitrous oxide gas has since maintained the first place as an anæsthetic for use in modern dental practice. Its utility in this connection and also, in some respects, in general surgery, has been much enhanced by the success of Dr. E. Andrews, of Chicago, in 1868, in obtaining a non-asphyxial form of anæsthesia by the combined use of oxygen and nitrous oxide gas.

The work of Clover in demonstrating the advantages of air-limitation in administering ether, of the advantage of the use of nitrous oxide gas as a preliminary to etherization, and his improved methods of administering nitrous oxide gas, did much to lessen the popularity of chloroform.

Heated controversies arose as to the relative merits and demerits of chloroform and ether. Investigations into the physiological action and lethal manifestations of chloroform were be-

gun. The teaching of Syme and the Edinburgh school was that chloroform never produced primary depression of the heart. The report of the "Glasgow" committee of the British Medical Association in 1876 stated that blood pressure and cardiac action were distinctly lowered under chloroform; that respiration generally ceased before cardiac action, and that primary cardiac paralysis might occur.

To settle this dispute the first Hyderabad commission was appointed. The funds being furnished by the Nizam of Hyderabad at the suggestion of Surgeon-Major Lawrie, who upheld the teachings of Syme. The conclusions of the commission, after numerous experiments, were in accordance with the Edinburgh school, and were not accepted by the profession at large. A second commission, whose report appeared in 1891, essentially corroborated the conclusions of the first commission. Eminent physiologists soon demonstrated errors in the technical work of these commissions, and independent investigations by Wood, Hare, Hill, MacWilliam and others go to show that the fall of arterial tension is largely, if not wholly, due to the effect of chloroform upon the heart, and that even though respiration ceases before the heart action, the principle element in chloroform syncope is the effect upon the circulation.

The report of the Committee on Anæsthetics of the British Medical Association, rendered in 1900, states that ether is singularly free from danger in healthy subjects, and that in the large majority of cases of danger from chloroform the symptoms are those of primary failure of the circulation.

In the early days of anæsthesia the almost sole object was to prevent pain during operations, without regard to partial consciousness or physical disturbances on the part of the patient. Later on it became evident that total unconsciousness could readily and safely be induced even if it were necessary to repeat the administration of the anæsthetic. The possibility of prolonged and complete anæsthesia gradually came to be realized, and at the present time it is possible to rapidly induce complete anæsthesia and continue it for an indefinite period without any of the excitement and disturbance which was formerly so familiar a feature of the administration of general anæsthetics.

Among others of the many substances that have been more or

less used for the purpose of anæsthesia since the discovery of the practical application of the ones already considered in the induction of the anæsthetic state are a few that have obtained more or less recognition. Ethyl bromide, discovered by Serullas, in 1827, was introduced as an anæsthetic by Nunneley, of Leeds, in 1849. Ethidene dichloride, discovered by Regnault, was first used by Snow for anæsthetic purposes. Amylene, discovered by Balard, in 1844, was first employed by Snow. Pental, nitrogen, ethyl chloride, methyl oxide, ethylene or olefiant gas, and other substances have been employed as anæsthetics.

About two years ago a method of anæsthesia was introduced as a substitute for general anæsthesia. It is generally known as Bier's method, but should be, it is claimed, attributed to Corning, of New York. This method is by medullary cocainization by the sub-arachnoid injection in the lumbar region of a solution of cocaine. Though this method is not one of complete general anæsthesia it is of interest in this connection as a substitute for general anæsthesia in severe operations where local anæsthesia through local injections is not possible. This method has had considerable employment since its introduction, but it is not yet determined that it will retain a place as a reliable and satisfactory method of anæsthesia.

CHAPTER II.

GENERAL PHYSIOLOGY.

General anæsthesia may be defined as a state of intoxication of the body in which there is suspended consciousness of more or less rapid induction and recovery, during which the vital reflexes are not affected, and which, aside from the anæsthetic period, affects tissue life and function to the least possible extent.

There are many agents capable of producing, in one way or another, an anæsthetic state more or less approximating that defined above, the principal ones of which will be considered hereafter.

An agent suitable for general anæsthesia must possess certain characteristics. It must be capable of inducing general insensibility to pain, and in surgical anæsthesia it must hold in abeyance muscular power also. It must be possible of introduction into the circulation without great difficulty or marked unpleasantness or danger to the subject. Its physiological effects must not be so rapidly acquired or so intense as to interfere with the control of its effects by the administrator. Its elimination must be complete, and sufficiently rapid to allow of an early return to the normal condition upon the discontinuance of the administration. Such agents as nitrous oxide, chloroform, ether, and bromide of ethyl fulfill these requirements more or less completely.

As a rule the toxicity of the agent increases directly with the rapidity with which anæsthesia may be induced, and according to Magill the toxicity of the agent increases in direct ratio to concentration of carbon in the radical of the agent. The addition of oxygen to the hydrocarbon molecule while not increasing the toxicity of the agent renders the induction of anæsthesia slower. The combination of a halogen with the organic radical increases toxicity which multiplies directly with the number of elements of the halogen introduced into the molecule, and also directly with the density and weight of the halogen in question. Chloroform, by means of the hyperchlorination of its molecule, is possessed of marked toxic properties which are partly compensated for by its active anæsthetic powers. If bromine in

equal number of atoms be substituted for chlorine the resulting bromide is possessed of greater toxicity. The halogens of great atomic weight may increase the toxicity of the molecules so as to render them dangerous even in the smallest quantities.

The entrance of the anæsthetic into the organism is accomplished, in those organisms possessing a circulatory system, by absorption. The introduction of the agent may be effected by its local application to the skin. This method may be effective in cold blooded animals as shown by Bernard in the case of frogs, because their elimination is slow. In warm blooded animals the more rapid elimination prevents this method from being effective. The stomach and rectum may be used as channels for the introduction, but for evident reasons this method is unreliable. The respiratory tract presents the best and most available channel for the introduction of anæsthetic agents because of the large area of the pulmonary capillary net-work of vessels, and the rapidity with which the blood from the lungs reaches that part of the organism upon which the chief effects of the anæsthetic are manifested,—the central nervous system.

The absorption of the anæsthetic from the pulmonary capillaries will depend on the tension of the agent in the air and its solubility in the blood. The former will vary with the temperature of the air and the barometric pressure. The absorption of the anæsthetic from the air in the alveoli is governed by the physical laws which control the interchange of gases between the alveoli and the blood. A prominent necessary factor in this process is the diffusion of air in the pulmonary alveoli. This diffusion of air is increased in proportion as the tidal air may be increased. In quiet respiration the tidal air is estimated as equal to 500 cm., and the alveolar capacity which is equal to from 2,000 to 3,000 cm. after respiration, may be changed about three and a half times between the extremes of forced inspiration and forced expiration. As the effect of all anæsthetics during the initial period of inhalation is to increase the depth of respiration the influence of the factor of diffusion of air in the alveoli as related to the interchange of gases between the alveoli and the blood is increased during this period of anæsthesia.

Snow stated the proposition that, as the relation of the proportion of vapor in the air breathed is to the proportion of vapor

the air will contain if saturated at the blood temperature, so is the proportion of vapor absorbed to the proportion the blood will dissolve.

The amount of anæsthetic absorbed is greater when the temperature of the air inhaled is high than when it is low, and the amount of anæsthetic necessary to produce a certain degree of anæsthesia is correspondingly less as is shown by the records of the amount of chloroform necessary to produce anæsthesia in hot countries. Chloroform also appears to be less dangerous in warm climates. A study of chloroform mortality by Thomas R. Evans shows that the majority of deaths occurred during the cold season. H. C. Wood thinks this is due to the more rapid elimination of chloroform in hot climates.

The fact that the quantity of chloroform necessary to induce anæsthesia may vary with the temperature of the inspired air is no indication that a greater or less amount of the anæsthetic is necessary to affect the neurons. So far as the effect of an anæsthetic agent on the nerve centers is concerned it depends on the facility with which the agent may reach the center, and the length of time it may be retained there.

The pulmonary tract constitutes the chief channel for the elimination of anæsthetics. Elimination also takes place through the glands of the gastric mucosa, and through other glands. The gastric elimination is in a measure the cause of vomiting, especially of that which occurs during the early part of the recovery from anæsthetics, and the recovery is usually rapid after vomiting has occurred. While it is not positively determined whether anæsthetics undergo any decomposition during their presence in the blood, elimination is more or less freely carried on by the respiratory tract according to the freedom of the air tract from obstruction, the depth and efficiency of respiration, the nature of the anæsthetic agent, and the method of administration.

Generally the amount of CO_2 eliminated is decreased. Rumpf found a decrease of 40 per cent. in the respiratory exchanges, and Richet found a decrease of 50 per cent. in the elimination of CO_2 in chloralized dogs. Bert's experiments with chloroform show a progressive diminution in O absorbed and of CO_2 given off, the difference being considerably greater with the latter than with the former. Lorrain Smith has shown that dyspnœa from change

in the gaseous composition of the blood may be due to a deficiency of oxygen (O-dyspnœa) and is characterized by frequent respiratory movements (hyperpnœa), vigorous inspirations, long duration, severity, rise in blood pressure, and motor disturbance.—symptoms similar to those of the initial period of anæsthesia, and in which they are directly related to the exclusion of O, especially with those agents which do not induce narcosis rapidly enough to exclude such symptoms, such as ether or chloroform.

Again dyspnœa may be due to an excess of carbonic acid CO_2-dyspnœa) and be characterized by slow respiratory rate, length and vigor of expiration, expiratory pause, and absence of motor disturbance,—symptoms similar to those of too deep or prolonged narcosis, especially in the late stages of anæsthesia.

The changes produced in the blood by anæsthetics are not fully understood, but generally speaking are not important. Alterations in the corpuscles have been described and are said to occur in the pulmonary capillaries. Richet states that blood which contains an anæsthetic in solution preserves, when shaken with air, its full ability for fixing oxygen.

Da Costa and Kalteyer have demonstrated that the anæsthetic state, the period preceding, and the period following, produces blood concentration. They conclude that: 1. The character of the change is usually a polycythæmia; rarely, an oligocythæmia. 2. The nature of this polycythæmia is best explained by a lessening of the watery elements of the plasma, thereby reducing the total volume of the sanguinis and causing concentration. 3. The three important factors incident to the polycythæmia are: (*a*) The period of preparatory operative treatment; (*b*) the anæsthetic state; and (*c*) the post-operative stage. 4. The blood inspissation is, as a rule, most pronounced just after the termination of the anæsthetic stage. 5. The hæmoglobin is always reduced absolutely. Apparent increase is never parallel with the rise in red blood cells. We must consider that etherization produces increased hæmolysis, and that in nature's efforts to rapidly replace the blood cells the regenerated cells are imperfectly supplied with hæmoglobin. 6. The duration of the anæsthetic state, and the amount of ether, influences the blood changes. 7. The amount of blood loss does not seem to affect the blood. 8. Whenever possible one or more blood examina-

tions should be made before giving an anæsthetic, and before preparatory treatment is instituted. On account of the hæmolysis, shown by the fall in corpuscular hæmoglobin after operation, a very low percentage of hæmoglobin must be regarded as a contraindication to general anæsthesia.

The nervous system shows the first and most marked effects of an anæsthetic, and the most highly organized part of this system is first and chiefly affected. The other economic systems are usually not affected to any important extent. There is irritation, depression, and finally paralysis of the nervous system. The cerebral cortex, the cerebellum and ganglia of the base, the sensory tracts and centers of the cord, the cerebrospinal motor tracts and centers, and the respiratory and cardiac centers seem to be affected in the order mentioned.

In the induction stage there may be analgesia without complete unconsciousness. This, according to Dastre, is due to the anæsthetic affecting the sensory nuclei of the cord or cerebral ganglia before the cortical areas are involved. Other physiologists think the interruption is in the cortical areas. Analgesia without unconsciousness in the later stages of anæsthesia is rare but occurs in exceptional instances. Sight is usually lost before hearing.

The motor system is first excited, then depressed and paralysed. The centers of complex co-ordinate movement are first affected, then those governing ordinary muscle movements, and finally the automatic centers of respiration and circulation are involved.

The exact nature of the changes in the central nervous system which result in anæsthesia are not fully understood. The similarity of the symptoms to those of sleep, both in relation to anæsthesia and other characteristics has led to the supposition that the conditions were analogous, but the intimate nature of both conditions is not sufficiently understood to warrant a definite conclusion in this respect. Even if we accept the theory that sleep is not so much the result of changes, within the neurons from any agent, as the effect of change in the dentritic processes which connect the individual neurons, we are no nearer a direct solution of the nature of the conditions. The effect of an anæsthetic on the nerve centers is temporary, and whether the effect

is due to a change in the protoplasm of the nerve cells induced by the anæsthetic in the blood, or whether the anæsthetic produces its effect by interfering with processes of oxidation which are necessary to the functional integrity of the nerve centers is impossible at present to state.

In this connection, however, the phenomena attending disordered action of neurons under the influence of anæsthetic agents may be better understood, and the condition of the anæsthetized subject be more readily appreciated by the anæsthetizer if it be borne in mind that the neuronic groups undergo gradual and successive development in complexity, involving; in relation to function, respectively those governing respiration and circulation, the organic reflexes, the special reflexes, and co-ordination—sensory, motor, motor-sensory association, consciousness, and ideatory. The structural stability of these centers is greater in the oldest centers, while those neuronic groups developed last show least stability.

Neuronic complexity or integrity is associated with high lecithin and fat compounds. These compounds are least stable in the highest neurons or those of latest development. The hydrocarbon compounds (anæsthetics) displace H_2O or dissolve the fat compounds, and first affect those groups which are of least stability, i. e., those of latest development. The hydrocarbon compounds are therefore anæsthetic in proportion to their ability to affect lecithin and fat compounds, and their effect on the neuronic groups is in inverse order to the developmental stability of these groups.

The effect of anæsthetics on the respiration vary exceedingly according to the nature of the agent, the type of the subject, and the manner of administration. There is a local irritant action on the respiratory passages, more marked with some agents than with others. This results in more or less obstruction to breathing from spasm or swelling. As the inhalation proceeds stimulation of the respiratory centers causes quicker and deeper breathing. Irregular forms of breathing may occur from too little oxygen, as in the close administration of volatile agents, or from CO_2 dyspnœa, as in rebreathing during the administration, or from psychical causes. So-called "physiological apnœa" may occur with oxygen and nitrous oxide and, at times, with other

agents. Cheyne-Stokes breathing may be present in old people or in debilitated subjects under anæsthesia. Stertor is due to respiratory obstruction. The term stertor is applied to the snoring sounds of respiration under anæsthesia. It is generally caused by vibration of the tongue against the pharyngeal wall, and has been termed pharyngeal stertor. Other forms of stertor described are: Nasal, buccal, palatine, laryngeal, and mucous stertor.

The muscular phenomena present under anæsthesia are chiefly: Nervous manifestations, conscious or sub-conscious voluntary movements, unconscious excitement movements, tonic spasm, clonic spasm, co-ordinate movements under deep anæsthesia, fine tremor, and reflex movements.

Reflex movements are of importance as guides to the state of anæsthesia. They are exaggerated during the earlier stages of the administration, become diminished as anæsthesia is reached, and during surgical anæsthesia most of the reflexes are lost, while during toxic conditions the reflexes are absent. The corneal, laryngeal, pharyngeal, vesical, rectal, and genital reflexes are maintained longest. The power of the spinal cord to transmit sensory impulses is maintained late. The vaso-motor centers maintain their power late. The cardiac accelerator and inhibitory centers are supposed to be more irritable under light than deep anæsthesia, but their action may not be abolished under profound anæsthesia. The respiratory centers may remain active to reflex stimulation under the most profound anæsthesia.

The heart action is stimulated and quickened during the first stages of anæsthesia, and the blood pressure, as a rule, is raised. Later the heart's action becomes less excitable, and varies from incidental influences. Under complete anæsthesia there may be some degree of cardiac dilatation. In the stage of bulbar paralysis the heart's action is feeble, irregular, imperceptible, and there is paralysis of the cardiac ganglia and of the automatic power of the myocardium.

The more or less gradual occurrence of the effects produced by anæsthetics has led to describing the effects as occurring in certain stages. Such division is more arbitrary in the case of the rapid agents than with the slower ones. Clinically we recognize three stages with more or less definiteness. Some observ-

ers have divided the same periods into four stages. Physiologically we must add to the three clinical stages a fourth, that of bulbar paralysis. The following division given by Hewitt fairly represents in a general way the sequel of events. 1st stage: Stage of disordered consciousness and analgesia; 2d stage: Stage of unconscious reflex activity; 3d stage: Stage of surgical anæsthesia or coma; 4th stage: Stage of bulbar paralysis.

CHAPTER III.

THE SELECTION OF A GENERAL ANÆSTHETIC WITH REFERENCE TO THE COMPARATIVE DANGERS OF THE AGENTS EMPLOYED.

The development and dissemination of knowledge regarding the practical administration of anæsthetics has gradually abrogated the bias formerly shown by various observers toward this or that anæsthetic, and it is now recognized that the exclusive employment of one anæsthetic is unjustifiable. The minimum of danger is secured by recognizing the following factors in relation to safety: The adaptability of the agent to the individual to be anæsthetized; the relation of the anæsthetic to the nature of the operation to be performed; the proper technique to be used with the agent selected with regard to the above considerations; and the experience and skill of the administrator.

With reference purely to the comparative dangers of the agent employed in routine or ordinary practice without regard to special conditions, we have to consider which anæsthetic is most free from danger to life in an abstract way. As far as actual danger to life is concerned, nitrous oxide gas is undoubtedly the safest anæsthetic known. Hewitt, in a search through medical and dental journals covering a period of forty years, found records of only thirty deaths, several of which were not due to the anæsthetic directly. Nitrous oxide and oxygen is possibly less dangerous even than the pure gas, though the difference is slight. Goldman, Gardner, and others endorse the safety of nitrous oxide with or without oxygen. No fatalities are recorded with the latter combination. The limitations of nitrous oxide in relation to general surgery, however, causes our chief interest in this connection to center in those agents more suitable for producing prolonged anæsthesia. Of these agents the decision is mainly between ether and chloroform.

We find that in different countries, in different sections of the same country, in individual cities, and in individual hospitals that surgeons differ as to the choice between ether and chloroform according as their experience has been greater with the

one than with the other. In the Eastern States ether is generally preferred, while in the Southern States and in some of the Western States chloroform is mostly used. In Germany chloroform was usually employed until within the last ten years when ether has been largely used owing chiefly to the influence of Gurlt's showing. In England chloroform was for a long time the chief anæsthetic but of late years ether has been gaining in use.

Statistics regarding the relative fatality of anæsthetics are unreliable because of the impossibility of excluding various contributory causes. They may be regarded as roughly indicative of the relative dangers of anæsthetics. Some of the leading statistics are as follows:

ANÆSTHETIC	ADMINISTRATIONS	DEATHS	DEATH RATE	REPORTED BY
Chloroform	35,162	11	1-3,196	Richardson, of London, ('92).
Ether	8,431	1	1-8,431	
Chloroform	524,507	161	1-3,258	Jullard, of Geneva, (1891).
Ether	314,738	21	1-14,987	
Chloroform	152,260	53	1-2,873	Ormsb", of Dublin, (1877).
Ether	92,815	4	1,23,204	
Bichloride of Methylene	10,000	2	1-5,000	
Chloroforn and Ether	11,176	2	1-5,558	
Chloroform	30,871	21	1-1,470	St. Bartholomew's Hospital, London, ('76-'96).
Ether and Gas and Ether	27,916	4	1-6,979	
Chloroform	22,656	4	1-5,664	German Surg. Society, (1890)
Chloroform	133,122	46	1-2,894	Körte, of Germany, (1894).
Chloroform	13,393	18	1-744	British Med. Ass'n., (1900).
Ether	4,595	6	1-765	

In India where choloform appears to be less dangerous than in colder countries Neve recorded 78,407 administrations with but three deaths. The ratio of cases of danger to the total administrations in the report of the British Medical Association (1900), was 1.030 per cent. for chloroform, and 0.304 per cent. for ether.

Ether appears to be generally recognized as absolutely the safest anæsthetic after nitrous oxide gas. Its stimulant effect on the heart and respiration, and the fact that evident and early respiratory difficulty is almost always present in case of danger, are strong factors in its safety.

More careful discrimination in the selection of anæsthetics

than was formerly employed leads to the position emphasized by Mikulicz, that abstract safety is not now the only question, but that the practical points are: In which cases shall general anæsthesia be substituted for local anæsthesia; what is the safest general anæsthetic for the individual and operation in question?

A half century's experience with anæsthetics has brought the conviction that improper selection of the agent, and lack of skill and judgment in the administrator constitute a large share of the dangers from any anæsthetic. So far as available knowledge is to be gained from statistics it points to greater danger from chloroform than from ether. Failure of both heart and respiration, without any discoverable cause, are more frequent under chloroform than under ether. Chloroform in healthy individuals may cause fatty degeneration in the heart, liver, and kidneys, which may be responsible for late deaths after chloroform anæsthesia. Such changes are rare and slight from ether. On the other hand post-anæsthetic complications, such as pneumonia, acute œdema, or thrombosis with or without embolism of the peripheral veins of the lower extremities, are more frequent from ether than from chloroform.

These facts are the cause of the difference of opinion on the relative safety of these two agents.

Obese subjects, and alcoholics take ether badly, and in these chloroform may be the safest and best anæsthetic. In some subjects, and for long operations, and with an inexperienced administrator, ether is generally safer. In healthy subjects presenting no special indications for other anæsthetics, ether is undoubtedly safer than chloroform.

The importance of the method of administration, and the skill of the administrator in relation to the danger of any anæsthetic is being more and more recognized. The greater safety of nitrous oxide and oxygen over the gas alone is recognized, but the difference is too slight to offset the greater skill necessary to administer the combined agents.

The semi-open methods of administering ether are safer than the close methods, especially in the hands of inexperienced persons.

In administering chloroform the drop method is generally recognized as the safest, and most anæsthetists agree with Sippel

that the complicated methods of administering chloroform do not eliminate its dangers. Individual peculiarities in regard to the amount of chloroform necessary to produce narcosis render various forms of apparatus more or less unsatisfactory.

The A. C. E. mixture probably should occupy an intermediate position with ether and chloroform as regards safety. There are special conditions in which it may be the agent of choice. The short term anæsthetics, such as bromide of ethyl, under certain conditions may be the anæsthetic of choice both from the standpoint of convenience and of safety.

Generally speaking anæsthetics present a higher danger rate during the winter than during the summer months. The difference with choloroform is slight while with ether it is somewhat higher than with chloroform, owing somewhat to the greater likelihood of post-anæsthetic complications affecting the respiratory organs when ether has been the agent employed. With the other anæsthetics the difference between winter and summer as regards the danger rate is unimportant.

CHAPTER IV.

THE SELECTION OF THE ANÆSTHETIC WITH REFERENCE TO THE PATIENT.

There are many considerations with reference directly to the patient which have an important bearing on the question of the best anæsthetic to employ in individual cases. The popular belief that absolutely healthy subjects are the best for anæsthetic administration is not strictly true. If the dangers from an anæsthetic were always of toxic origin then they would probably be strictly related to the general physical condition of the subject. But the asphyxial dangers which are intercurrent with the administration are more frequent and pronounced in certain types of individuals which represent the more robust subjects. We find, therefore, that persons whose general health and physical condition is not up to the standard as a rule take anæsthetics with less disturbance, and the administration presents fewer cases of danger, than is the case with more healthy subjects. Persons with advanced organic disease will show an increase in the incidence rate of dangers and complications over healthy subjects, but the difference is not so marked as has been supposed, especially when the anæsthetic has been intelligently selected with reference to these special conditions.

Sex. There is a distinct difference both in the effects and in the danger rate from general anæsthetics in the two sexes. Females, generally, are more easily anæsthetized and exhibit a lower danger rate than males, although emotional disturbances are more frequent in women. The difference is much less marked at the extremes of life than during the period of middle life, while strong and masculine women, and weak and effeminate men exhibit the characteristics of males and females respectively regarding anæsthetization.

Anæsthetics are more commonly associated with dangers and complications in males than in females. Chloroform is said to be about twice as dangerous in males as in females. Ether is slightly more dangerous in females than in males, and while its complications are more frequent in ma' · they are generally

slight. The A. C. E. mixture is more dangerous in males than in females, but the difference is less marked than with chloroform. The relative dangers and complications of gas and ether are the same as with ether.

According to the report of the British Medical Association (1900), the ratio of danger is as follows, the danger rate of gas and ether being taken as a unit:

MALES.	
Chloroform	7.107
Ether	1.205
Gas and Ether	1.
A. C. E. Mixture	2.854
FEMALES.	
Chloroform	2.040
Ether	1.144
Gas and Ether	1.
A. C. E. Mixture	1.191

Age. If we take anæsthetics collectively and exclude the period of infancy, we find that the dangers increase *pari passu* as age increases. Chloroform is most dangerous during infancy and after thirty years of age, and least dangerous from ten to thirty years. Ether is less dangerous to infants than chloroform, and its period of greatest danger is from fifty to seventy years of age.

Anæsthesia has been safely produced in an infant of a few days, and in centenarians, but these extremes of life are dangerous periods for anæsthesia, and careful selection of agents is necessary.

In infants and young children nitrous oxide gas is an unsatisfactory and dangerous anæsthetic because of the liability of asphyxial troubles. Combined with oxygen the dangers are less. In children above six years of age nitrous oxide may be valuable as a preliminary agent to ether as this plan obviates the stage of excitement usually so marked in children under ether. Chloroform is a popular anæsthetic for children because of the readiness with which anæsthesia may be produced, the comparative freedom from excitement, and its less irritating effect on the upper respiratory tract. While chloroform is more readily taken by children and is less liable in them to cause respiratory and

circulatory embarrassment than ether, and should such trouble arise remedial measures are more effective in children than in adults, yet chloroform is not so free from danger in children as has been supposed. In infants the ready induction and tranquil nature of the narcosis may be misleading. Ether may be given to children with plenty of air and will be taken much better than is generally supposed. It is undoubtedly safer than chloroform. Nevertheless, if chloroform is very carefully given by the drop method, and care be exercised to withdraw the chloroform as soon

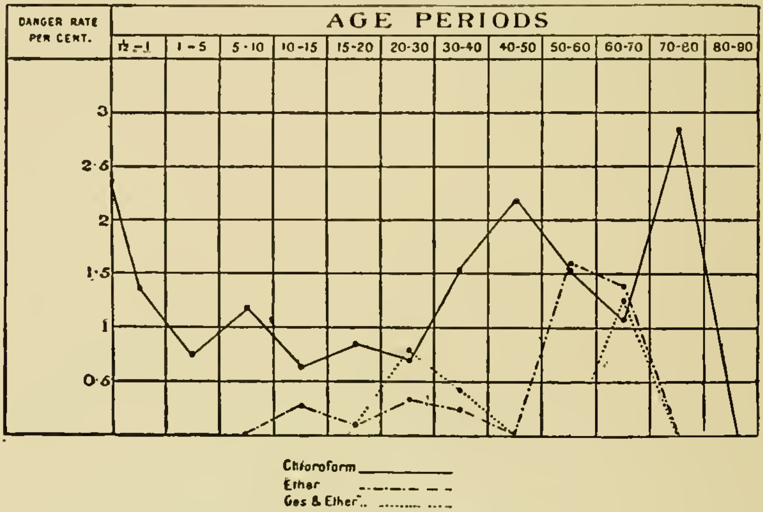


Chart showing relation of age to danger rate, according to Report of British Med. Ass'n, 1900.

as struggling or crying shows signs of ceasing, there will be comparatively little danger in the use of chloroform in children.

Some anæsthetists prefer chloroform, some ether, some the A. C. E. mixture, and some the chloroform-ether, or A. C. E.-ether sequence, for children. It is generally conceded that ether is safer in children than chloroform, though it is not so easy of administration.

Old people take anæsthetics better, comparatively, than persons in middle life. They are less subject to muscular spasm, have fewer respiratory difficulties, and require less of the anæsthetic. In the absence of senile lesions of the heart and obstructive conditions of the lungs they take ether well. The A. C. E.-

ether sequence is recommended as being better than the nitrous oxide-ether sequence. Nitrous oxide is not as safe in elderly people as in middle life, and in senile subjects should be given with oxygen. Chloroform is a satisfactory anæsthetic as far as facility of induction is concerned. It is not relatively as dangerous as in children if organic disease be not advanced. Some anæsthetists use chloroform or A. C. E. mixture as routine agents in persons over 60 years old, just as others the A. C. E. mixture in children under 10 years. The chart (Page 40) shows the relation of age to the danger rate.

General condition. Persons of a highly excitable temperament, and nervous, irritable people are generally troublesome to anæsthetize. Muscular phenomena are more apt to be manifested than in subjects of more equable temperament. It may be impossible to completely abolish the reflexes in excitable subjects, and may be dangerous to attempt to carry the narcosis far enough to do so. In hysterical subjects the corneal reflex may be absent even though anæsthesia be not fully induced.

Nitrous oxide is a good agent in excitable subjects provided the narcosis is long enough to answer the purpose, or the nitrous oxide-ether sequence may be used with benefit.

The A. C. E. mixture is often very satisfactory in neurotic subjects. The so-called interrupted ether narcosis is also a very satisfactory method. The administration is simply interrupted with sufficient frequency and regularity so as not to abolish completely the reflexes. This is sometimes confused with the use of morphia or with local anæsthesia.

Anæmic, debilitated, or *cachectic subjects* usually require less anæsthetic than robust subjects. All anæsthetics should be given without much limitation of air to these patients. Nitrous oxide with oxygen, interrupted ether narcosis, A. C. E.-ether, or chloroform-ether sequence may be used. Profound anæsthesia should be avoided.

Vigorous, healthy and plethoric subjects require more anæsthetic, exhibit more muscular and general excitement, and relatively sustain a higher danger rate than less healthy subjects. Florid subjects require considerable anæsthetic and should be kept deeply anæsthetized to prevent reflex disturbances. The

amount of air must be limited, and with nitrous oxide it may be necessary to induce a marked degree of cyanosis.

Obese subjects do not tolerate well any method of administration admitting of but little air. The A. C. E. mixture or chloroform is therefore best tolerated, though in some instances the chloroform-ether sequence is most satisfactory.

Alcoholic subjects usually require a large amount of anæsthetic. The stage of excitement is prolonged, muscular and reflex movements are marked and persistent, and muscular relaxation may not be complete. Nitrous oxide and oxygen is not satisfactory, and even with the pure gas it may be impossible to secure complete anæsthesia. If chloroform be used care must be exercised during the stage of muscular rigidity and excitement. The A. C. E.-ether sequence is often advantageous in these subjects.

Drug habitues are generally more sensitive to the action of anæsthetics, and if the administration should closely follow the use of some drug, especially morphine, great care should be exercised.

Tobacco users may take anæsthetics badly, both because of irritable conditions of the upper air passages, and because of the degree of muscular spasm, especially of the muscles of the jaws, and obstructive breathing likely to ensue in excessive users of tobacco.

Menstruation. While it is customary not to administer anæsthetics during menstruation, owing to a possible disturbing effect upon this function, there is no special objection to so doing if occasion requires, and the presence of the menstrual flow has no bearing on the selection of an anæsthetic.

Pregnancy. The pregnant state presents no special contraindication to the administration of an anæsthetic, at least in the earlier months. Nitrous oxide should not be given after the fifth month. Abortion has followed its use in women not five months pregnant. If used at all it is best in combination with oxygen. In the late months of pregnancy we may use chloroform, the A. C. E. mixture, or the A. C. E.-ether sequence. Care should be exercised in preparing the patient in order to prevent after-vomiting.

Lactation presents no contraindication to general anæsthesia, and no special indications for particular agents.

Frequent anæsthetization may develop a lack of sensitiveness to anæsthetics, and such subjects may grow progressively harder to anæsthetize. They are likely to exhibit marked signs of irritability such as vomiting, swallowing, coughing, and obstructive breathing.

PATHOLOGIC CONDITIONS. The lymphatic diathesis, a condition characterized by enlarged tonsils, lymph follicles and glands, of the follicles at the base of the tongue, of the spleen, of the thymus gland, probably of the heart from dilatation, and associated or not with tubercular glandular enlargement, also with naso-pharyngeal growths, is a condition liable to be associated with sudden, dangerous syncope or with death under chloroform. In this condition ether is safer and otherwise probably more satisfactory. The nitrous oxide-ether sequence may be used.

Condition of the blood. Hamilton Fish says that safety in anæsthesia, and operative procedures, is dependent first on a hæmoglobin percentage over and above that required for its normal duties; and a normal or increased number of polynuclear neutrophiles. He states that in individuals whose blood presents a hæmaglobin percentage of 50 or less, the anæsthetic vapor produces an increased pathological condition by forced abstraction of oxygen from the tissues ill-conditioned to part with it. Mikulicz does not operate when the hæmoglobin percentage is under 30 per cent. Da Costa and Kalteyer think operation dangerous with a percentage of hæmoglobin below fifty per cent.

Morbid growths of the mouth, tongue, palate, tonsils, pharynx, or epiglottis are liable to cause trouble from muscular enlargement under close methods of administration. Nitrous oxide and oxygen is therefore much safer than the pure gas. The nitrous oxide-ether sequence may be used. In some instances chloroform is the best agent if carefully administered.

In laryngeal diseases and chronic stenosis of the upper air tract chloroform, according to Semon, is preferable as ether increases the dyspnœa and liability to pulmonary complications. Hewitt thinks chloroform the only admissable anæsthetic in such cases, and that the depth of anæsthesia should be in inverse ratio to the degree of obstruction. Light degrees of obstruction

do not interfere with the administration, but marked degrees of obstruction render anæsthesia dangerous, the work of respiration depending on muscles which are incapable of overcoming the resistance to breathing. Respiratory arrest may occur even though the corneal reflex be present. In paralysis of the abductors of the vocal cords it may be necessary to keep the chin pulled forcibly away from the sternum in order to prevent obstruction from approximation of the vocal cords. The question of tracheotomy and the administration of chloroform through the tube should be considered in all cases of stenosis of the upper air passages from disease or pressure.

Diseases of the bronchi, lungs, or pleuræ, do not, as a rule, afford such direct indications as is given by the nature and length of the proposed operation. Patients with affections of the respiratory tract do not show as great a tendency to reflex manifestations as do other subjects, and the difficulties attending anæsthetization in chronic cases are relatively not so great as in acute cases because the lungs accommodate themselves to the altered conditions. If the operation is short, nitrous oxide and oxygen may be used, though as with all anæsthetics profound anæsthesia should be avoided. Ether may be used in comparatively short operations, and if cyanosis and expiratory difficulty arises the ether may be changed to chloroform or the A. C. E. mixture. In short operations chloroform or the A. C. E. mixture are probably best. In recent inflammatory states, especially if the heart is not as good as could be wished, the A. C. E.-ether sequence is to be recommended. In acute lung troubles Silk prefers chloroform, while in those not in the acute stage he prefers the A. C. E. mixture, subsequently increasing the percentage of ether. Patients with chronic pleurisy, fibroid phthisis, or emphysema usually take ether well. The report of the British Medical Association (1900), calls attention to the comparative freedom from danger in the lung cases, especially those of phthisis. Cases of acute or chronic bronchitis, or acute tuberculosis with marked catarrhal conditions are safer from after-complications if chloroform be used.

Diseases of the heart and blood vessels. Variations in the pulse rate do not, as a rule, modify the danger rate from anæsthetics, providing the pulse is strong and full. Cases with a

pulse rate as low as 25 per minute have been successfully anæsthetized. The pulse usually becomes more rapid. A pulse above 100 per minute usually slows under anæsthesia, unless the rate be due to shock or exhaustion, when it will rise in rate under the anæsthetic. An irregular pulse may become rhythmical under anæsthesia, and in any event usually improves in its rhythm. Allorrhythmia may be sustained or may disappear under anæsthesia.

Functional disturbances of the heart do not affect, to any appreciable extent, the danger rate of anæsthetics. Valvular affections do not, as a rule, affect the danger rate only in so far as they modify the dynamic integrity of the heart muscle. The condition of the myocardium is the vital question, and the only direct relation to the danger rate which a specific valvular affection may have is through its tendency to develop myocardial inability. According to H. C. Wood, "The key to the situation is not the valvular lesion, but the condition of the muscle, and ether is the anæsthetic of choice." Finney says, "In the myocardial affections only do anæsthetics exert any marked bad effect. In the valvular diseases their influence is very slight, but yet appreciable. In the functional disturbances they are insignificant." If compensation is good there is no great liability to danger. Marked degrees of mitral or pulmonary stenosis, and of aortic regurgitation not fully compensated for, are probably most often associated with danger. Danger will also be present in direct ratio to excess of dilatation. The great difficulty is to judge accurately as to the condition of the heart muscle. This is at times most difficult to do, as it is possible for degeneration to be present to a serious extent without definite physical alteration in the heart. On the other hand if compensation be good the effect of any anæsthetic will often be to improve the circulation, even though marked physical alterations have taken place in the heart.

Ether is generally considered the safest anæsthetic in heart disease. Nitrous oxide and oxygen is recommended by some, but it is doubtful if nitrous oxide in any form should be employed in cases of myocardial disease. Hewitt recommends A. C. E. mixture and the A. C. E.-ether sequence. Chloroform is generally condemned, though if properly administered by the drop

method it is not as dangerous in cardiac disease as is generally supposed. I have administered chloroform to subjects in whom there was every reason to expect trouble, so far, at least, as previous knowledge of the condition of the heart muscle would indicate, and yet have had no serious trouble. Wood thinks the shock from a severe surgical operation would be more fatal to a fatty heart than the effect of a general anæsthetic. This is undoubtedly true, for many patients with advanced fatty or other degeneration of the heart muscle have been anæsthetized without untoward symptoms. Chronic interstitial or granular degeneration of the heart muscle, resulting from vascular degeneration, are probably the most dangerous cardiac conditions as related to general anæsthesia, aside from recent dilatation or the advanced stages of the hyposystolic period of chronic cardiopathies. All methods of administration should be cautiously conducted and plenty of air admitted.

Chronic vascular disease of sclerotic or atheromatous nature with high arterial tension is probably more dangerous under ether than under chloroform or A. C. E. mixture; as these conditions occur late in life there is not so great a tendency to reflex disturbances under chloroform and this agent is correspondingly safer. In markedly atheromatous subjects there may be slightly increased danger from cerebral hæmorrhage, which Hewitt thinks is lessened by using A. C. E. mixture or chloroform in preference to ether. Ether is strongly contraindicated in subjects who have suffered previous attacks of apoplexy. Care must be exercised to prevent straining, coughing, or struggling by proceeding slowly with the anæsthetic, especially in cases of aneurism. In intrathoracic aneurism chloroform should always be used in preference to ether.

Patients with *venous thrombus* should not be moved more than can be helped. Struggling and excitement must be avoided. Chloroform, A. C. E. mixture, or A. C. E.-ether sequence are indicated.

Abdominal conditions such as peritonitis, intestinal obstruction, ascites, ovarian cysts, etc., may mechanically alter the type of respiration to the thoracic type. Anæsthetics must be carefully given. Chloroform, A. C. E. mixture or the chloroform-ether, or A. C. E.-ether sequence may be used, the change being made as

the abdominal tension is relieved, light anæsthesia being employed before this. Patients with marked acute intestinal obstruction are bad subjects for anæsthetics. The stomach is frequently not empty, they are often under the influence of stimulants or morphine, they vomit readily, and syncope and collapse are frequent. Nitrous oxide is not admissable, chloroform, or A. C. E. mixture are preferable. Ether, or A. C. E.-ether sequence may be admitted with whichever agent is employed.

Exhaustion, shock, and collapse are frequently present when the necessity for anæsthetization arises. As a rule such patients require small amounts of anæsthetic, especially when there is exhaustion from chronic disease. The pulse is generally improved by the anæsthetic, but marked depression may follow its withdrawal. Ether, cautiously given, by an open inhaler, is satisfactory, or chloroform by the drop method may be used. In shock and collapse the increase in the danger rate is somewhat greater than with exhaustion alone. This increase seems to apply somewhat more to chloroform than to ether, and the latter agent either alone or preceded by chloroform or A. C. E. mixture is most generally used. McCardie thinks that ether is strongly indicated in shock or collapse.

Kidney disease has long been supposed to contraindicate the administration of ether. Opinion is much divided on this point, though prolonged etherization is generally discouraged. Wood says that Thomas A. Emmet was first to report cases of anuria following ether narcosis in individuals suffering from chronic Bright's disease, but we know that chloroform may have the same effect. He thinks both are contraindicated in advanced nephritis, but prefers ether if anæsthesia be necessary. Many observations on the effect of these drugs on the kidneys show that albumen and casts are found in about 25 per cent. of the cases. The percentage is slightly higher after ether but the changes from chloroform appear to be more profound. Some authorities think that ether is contraindicated in kidney disease, some prefer the A. C. E. mixture. Kemp thinks that about 5 per cent. of ether cases are fatal from renal complications. On the other hand Buxton and Levy are not satisfied that ether exerts unfavorable effects on the kidneys when properly administered.

Opinion and statistics vary so greatly on this point that a definite conclusion cannot at present be stated.

Diabetes. The unqualified statement is often made that diabetics take anæsthetics well, but the experience of most observers agree with the statements of Pavy, that in diabetics who are in good condition with little or no sugar in the urine, the administration of anæsthetics is attended with no special risk, but in those who show large amounts of sugar the administration of anæsthetics especially for protracted operations is liable to be followed by diabetic coma. The patient, therefore, should have careful preliminary treatment; the anæsthetic should be chosen with a view to avoiding excitement, after-vomiting and complications; the administration should be made as short as possible. Eastes says that diabetics take ether and chloroform well. Probably the latter or the A. C. E. mixture is safest for these patients.

Nervous diseases. Subjects with cerebral abscess, tumor, intracranial hæmorrhage, depressed fractures, etc., or who are toxic from various causes, may be sufficiently comatose that very little if any anæsthetic will be necessary. Hewitt calls attention to the fact that patients with tumor may show a tendency to respiratory failure due to increased intracranial tension, and in them even slight anæsthesia may entirely suspend respiration.

Respiratory disturbances are liable to occur in subjects of chronic nervous disease. Epileptic subjects may be safely anæsthetized. There may be a tendency to muscular spasm, or epileptic paroxysm may occur during the early part of the administration. Ether is probably the best agent generally for patients with nervous disease.

According to Savage, the insane take anæsthetics well, and take the various anæsthetics with equal safety. Chloroform produces marked after-effects in maniacal subjects, severe maniacal attacks being not uncommon.

CHAPTER V.

THE SELECTION OF AN ANÆSTHETIC WITH REFERENCE TO THE OPERATION.

The bearing of the operation to be performed on the selection of the anæsthetic is chiefly through the facts that certain anæsthetics are better adapted to the performance of certain operations than are others; that more profound anæsthesia is necessary for some surgical procedures than for others; that certain operative measures affect the respiration and circulation more than others; and that in certain postures some anæsthetics are more likely to cause respiratory or circulatory disturbances during operative proceedings than are others.

Respiration, which is usually deeper and quicker under anæsthesia, may become obstructed from surgical manipulations in operations about the air passages, or from the effect of the stimulation of operative measures on other portions of the body.

The circulation may become depressed (surgical shock) from hæmorrhage, prolonged surgical measures, or from reflex inhibition from the surgical proceeding, as in skin incisions, etc., during light anæsthesia, especially with chloroform. Hewitt believes that surgical shock from reflex causes also occurs with profound anæsthesia, and that such a degree of narcosis does not protect against shock. He favors the view that ether is more protective than chloroform against reflex inhibition of the circulation.

In patients in a condition of shock or collapse ether is generally preferred as being more stimulating to the respiration and circulation than other agents.

Short operations may be performed under the short-term anæsthetics, as nitrous oxide, pure or with oxygen, ethyl bromide, etc. Prolonged operations, especially abdominal operations should be performed under ether or chloroform.

For operations where complete muscular relaxation is necessary ether is most reliable, though at times it may be necessary to follow with chloroform in order to secure relaxation.

Brain and spinal cord. Chloroform is generally preferred. In spina bifida in infants ether is preferred by some.

Ophthalmic operations. Chloroform is preferred by many. The high death rate from chloroform in ophthalmic practice is partly due to the position of the head which favors obstruction to breathing, from mucus, saliva, retracted tongue, etc., also to the difficulty of maintaining an even degree of narcosis. Ether is preferred by some, especially in strabismus operations in children. The A. C. E. mixture, chloroform, or these in sequence with ether, may be advisable. For enucleation of the eye-ball the patient's general condition will determine the anæsthetic. When in elderly people, ether is safest. McCardie recommends gas and oxygen in squint operations in subjects above ten years, enough oxygen being given to obviate congestion.

Operations on the face, jaws, lips, tongue, palate, tonsils, nose, and naso-pharynx. If these operations are short, not exceeding 30 or 40 seconds, the short-term anæsthetics, such as nitrous oxide, or ethyl bromide, may be used. If a little longer anæsthesia is necessary nitrous oxide and oxygen may be used. If an available period of from 1 to 5 or 10 minutes is desired a single administration of ether, possibly preceded by chloroform or A. C. E. mixture, will often answer. If longer anæsthesia than this is necessary the ether-chloroform sequence recommended by Hewitt, White, and others, is useful. The former recommends deep anæsthesia by ether, suspension until slight conjunctival reflex, swallowing, or cough, appears, control these by cautiously giving chloroform, begin operation as reflexes disappear. Keep up a moderately deep anæsthesia. Many operators prefer chloroform alone.

In those cases where the anæsthetic is best administered through a mouth or nose tube chloroform may be given from some inhaler, such as the Junker, to which a tube is attached and passed through the nose into the pharynx, or it may be passed into the side of the mouth, or a gag with a tube attachment may be used (*vide* Fig. 1).

In operations upon the palate and throat some object to ether because of the greater vascularity under its influence. Howard claims that ether does not increase hæmorrhage in throat operations. In stenotic conditions of the air passages ether is not admissable because of obstructive congestion. Chloroform should be used. For adenoid growths some prefer chloroform

(Semon), or the A. C. E.-ether sequence (McCardie), or nitrous oxide, gas-ether, chloroform, A. C. E., or ether for quick operations, and nitrous oxide-ether, or, in children under 4 or 5 years, chloroform for longer operations (Hewitt).

For tonsillotomy, gas-ether or chloroform-ether sequence may be given in the dorsal position and the patient propped up for operation.

For the extraction of teeth. Nitrous oxide is the recognized anæsthetic. It may be used with or without oxygen as circumstances dictate. If a longer available period is desired than usually is the case, one of the methods of prolonging nitrous oxide

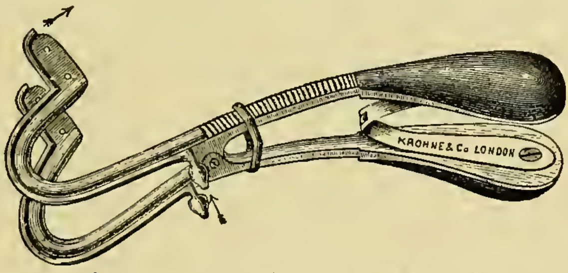


Fig. 1.—Hewitt's Modification of Mason's gag.

Fig. 1. Bent metal tubes are brazed to the arms of an ordinary Mason's gag. To one of these tubes the tubing from a Junker's inhaler is attached. The chloroform is thus transmitted along the tube to the back of the throat. The gag should be adjusted far back in the mouth.

anæsthesia may be used, as described under the administration of the gas. If the operation is a prolonged one the nitrous oxide-ether sequence is probably the best. Chloroform should not be used unless in some exceptional cases.

Operations on the larynx and trachea. Chloroform is generally the best anæsthetic. Some prefer the A. C. E.-ether-chloroform sequence. In excision of the larynx, thyrotomy, etc., a preliminary tracheotomy will probably be performed, and the anæsthetic (chloroform) should be administered from some such apparatus as the Junker inhaler by means of a tube passed into the tracheotomy tube a short distance. If the Trendelenberg air ball around the tracheotomy tube is employed (*vide* Fig. 2) there will be no trouble from the entrance of blood into the trachea during the chief operation.

Chloroform alone should be used for intra-laryngeal opera-

tions in children when done under general anæsthesia. The previous local use of a dilute solution of cocaine will diminish bleeding, salivation, and obviate the necessity of profound anæsthesia.

Tracheotomy and laryngotomy should be done under chloroform alone if there is any difficulty of breathing. If there is not difficulty of breathing the A. C. E.-ether, or nitrous oxide-ether sequence may precede the chloroform if desirable.

Operations on the neck exclusive of the air tract. These operations are likely to be prolonged, and important vessels and nerves are disturbed. Surgical shock is likely to be manifested. As deep anæsthesia as is compatible with safety should be maintained, as coughing, straining, etc., increases the vascularity and interferes with the operator. Ether increases the vascularity

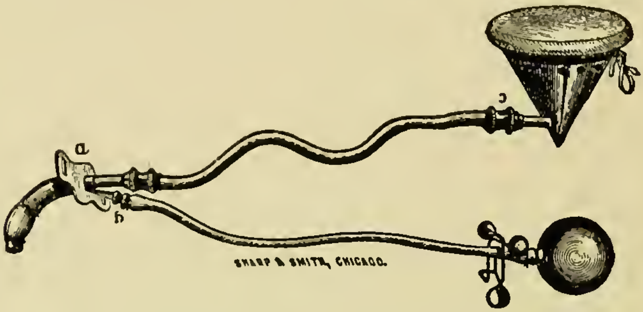


Fig. 2.—Trendelenburg's Trachea Tampon, Canula, and Inhaler.

Fig. 2. A trachea canula, the distal end of which is covered for about half an inch with a rubber sheath or bag surrounding the tube. The space between the sheath and canula is rendered air-tight and connected by a slender tube with a rubber air-forcing bulb.

By this means the bag may be inflated and as it is circular, and the tube in the center, it may completely fill the space between the canula and the tracheal walls, thus preventing a flow of blood below the tube. To the tube opening an inhaling apparatus is attached when desired, to facilitate the administration of an anæsthetic.

during the earlier part of the operation, but if given with plenty of air the effects, in this respect, are not markedly different from those of chloroform. Dyspnœa may be present in thyroid enlargement and be due to pressure. If pressure is marked chloroform should be used, and light anæsthesia maintained, as pressure atrophy of the cartilages may have occurred and complete abolition of muscular tone may cause kinking or displacement

of the trachea. In the worst cases local anæsthesia should be used, or a previous injection of morphine followed by light chloroform anæsthesia. In dissecting operations for diseased glands gas and ether may be used at first and a change made to chloroform as the operation begins. Some operators prefer chloroform for all operations upon the thyroid gland.

Operations upon the chest. The anæsthetic for these operations will depend on the condition of the patient. Chloroform is most convenient for the operator, but in many cases ether is preferable. The greater the interference with respiration the lighter should be the anæsthesia.

In chronic empyema the opposite lung has had time to adapt itself to the changed conditions, and the A. C. E.-ether-chloroform sequence may be used. In acute cases light anæsthesia under chloroform or one of its mixtures should be used. If the position will allow, gas and oxygen may be used in some cases. A full hypodermic dose of strychnia should be used previous to the administration in these cases.

Operations on the brain. The patient's general condition will determine the anæsthetic to be used. Ether is adapted to comparatively young subjects. There is less liability to secondary hæmorrhage after ether than after chloroform. For elderly people, or very fat subjects, chloroform or the A. C. E. mixture may be best. The chloroform-ether sequence may be used in patients in fairly good condition. Some prefer the gas-ether-chloroform, or the ether-chloroform sequence. Because of the condition of many of these patients anæsthesia should be conducted with care. With marked coma very little anæsthetic may be necessary.

Abdominal operations. These operations are generally more or less serious. The patient's condition is likely to be unfavorable; unpleasant effects during operation may interfere markedly with the surgical manipulations, and after-effects are likely to occur. Profound anæsthesia, as a rule, is necessary. Shock is likely to result from operations on the organs in the upper portion of the abdominal cavity from traction on their attachments or from manipulation of the peritoneum. Shock is also likely to follow manipulation of the intestines in intestinal or hernia operations. In these cases there are advantages in the

stimulant qualities of ether. Surgeons differ much as to the relative value of ether and chloroform in abdominal operations. Ether has, in some quarters, been counted out of abdominal operations because of the venous engorgement and the labored breathing it causes. The advantage of its stimulant action is supplemented by the safety of pushing it to the full abolition of inconvenient reflexes. The supposed tendency of ether to favor lung complications, which are very troublesome in patients with abdominal wounds, is probably offset by the Trendelenburg position so common now with most operators. This position also lessens venous congestion and interference with operative measures by the character of the breathing.

Ether or A. C. E. mixture are probably safest as routine agents, chloroform, or the gas-ether-chloroform sequence is satisfactory in the hands of experienced administrators. The A. C. E. mixture is good for children, elderly people, or those whose general condition is unsatisfactory. The ether-chloroform sequence is preferred by some if the operation is to prove a long one. In cases with great abdominal distention great care is necessary. The patient will usually be in the semi-recumbent position and unable to lie down. The A. C. E. mixture is recommended as being adapted to these cases. In intestinal obstruction anæsthesia may be dangerous if regurgitative vomiting should occur. The A. C. E. mixture with very light anæsthesia may be used. In some cases local anæsthesia may be safest, especially if the stomach is full of fluid and cannot be emptied by artificial means.

Operations on the rectum and genito-urinary tract. These operations usually demand a deep narcosis because of the sensitive condition of the parts and the nervous state of the patients. Operation should not be begun until profound anæsthesia has been induced. Ether is generally best because of the stimulation against shock and because of the thorough relaxation under its use. Ether is best for circumcision in weak children because of the shock of the operation. In operations on the bladder where distention is necessary the active breathing induced by ether may render it inadmissable, and chloroform or A. C. E. mixture advisable. In rectal surgery ether is much the safest agent because of the shock. The weak, nervous subject is most

likely to show bad effects at the time of the operation or afterward.

In operations on the kidney ether is preferable to chloroform if the organs are healthy, because of the shock. When the kidneys are diseased the A. C. E. mixture or chloroform is recommended by many observers. The nitrous oxide-ether-chloroform sequence is recommended by McCardie when the kidneys are fairly healthy, and chloroform, or any of its mixtures, if the kidneys are seriously affected.

Gynæcological operations. Women take anæsthetics better than men, and particularly chloroform, therefore its mixtures are adapted to these operations. Ether may be used in strong subjects with advantage. The chloroform-ether sequence is satisfactory.

Obstetric operations and parturition. Chloroform is the most generally used anæsthetic in this connection. Women under these circumstances bear chloroform so well that there is a general feeling of confidence in its safety, possibly a little over-rated for several deaths have been reported from chloroform given during labor, or for obstetric operations. Ether is recommended by some as being the proper agent for the full anæsthesia necessary for turning, craniotomy, instrumental delivery, etc., but nevertheless chloroform is so much more convenient, and, being relatively safe, it will probably continue to be chiefly used.

During labor chloroform should be given to produce an analgesia only. It should not be given if pains are feeble and irregular, when small doses retard labor, or when marked respiratory difficulty is present. Its administration should not be begun until distinct labor pains have appeared. A small quantity is given when the pain is approaching, just enough to relieve the severe part of the pain and to deepen respiration. The chloroform should be withdrawn as the pain begins to subside, and the patient should be allowed to recover from the effects of the drug in the interval of the pains. The general opinion is that profound narcosis increases the liability to uterine inertia and the danger of post-partum hæmorrhage. Most obstetricians recommend that consciousness should be allowed to return during the expulsion of the fœtus because of the liability of rupture of the perineum.

Among the reasons assigned for the comparative freedom from accident of chloroform anæsthesia during labor are these: That the element of fear of the anæsthetic is displaced by the woman's suffering and her desire for relief; that physiological hypertrophy of the heart protects against circulatory failure; that the deeper respiration and expulsive efforts prevent asphyxial difficulties and promote the pulmonary circulation and the emptying of the right heart; that high abdominal pressure prevents vaso-motor dilatation.

It is doubtful if the condition of the heart has any marked bearing on this question. The other causes may all have some effect.

Operations on the extremities, such as reduction of fractures and dislocations, examination and treatment of anchylosed and painful joints, are better managed with anæsthesia by ether than by chloroform because of the complete relaxation under ether, and the safety of pushing ether to its fullest extent. Chloroform has proven dangerous in this class of cases, particularly in injuries of the joints and bones as the patients are not always in the best condition for its administration.

CHAPTER VI.

BEFORE THE ADMINISTRATION OF AN ANÆSTHETIC.

There are certain considerations of importance preliminary to the administration of an anæsthetic which bear more or less directly on the success.

Time of day. The morning hours from 8 to 10 o'clock are generally considered the best for the administration. Statistics show that the danger and complication ratios for chloroform are lowest during the first quarter of the day, and increase progressively as the day advances. Of course other factors have much to do with this, but, all things considered, the morning hours are probably the safest for all anæsthetics. The stomach is empty, and the patient has not had the most of the day to worry about the operation. From 1 to 2 p. m. is probably the next best time for the administration, providing nothing has been eaten for breakfast except tea and toast.

Diet. Where the administration occurs in the morning the patient should not be allowed any breakfast. Ordinary, light meals may be taken the day before, but nothing after 8 p. m. the previous evening. Hearty meals taken the day before are apt to remain partially undigested, especially if the patient is worrying over the operation. If the administration is fixed for 1 or 2 p. m., tea or milk and toast may be taken at 8 a. m., and nothing afterward. When the administration is set for 11 or 12 o'clock, or for 4 or 5 in the afternoon, patients should be instructed not to eat their usual breakfast or luncheon. For the former hour a light breakfast of coffee and toast may be given at 7 a. m., while for the latter hour a light breakfast about 9:30 or 10 o'clock will answer.

These regulations of diet do not apply to the administration of nitrous oxide gas with as much force as they do to other anæsthetics. Although it is best to allow 2 or 3 hours to intervene between the taking of food and the administration of nitrous oxide, it is often taken shortly after food without trouble. When nitrous oxide is administered with air or oxygen the period previous to the administration should be governed by the same dietetic rules as apply to other anæsthetics.

In weak and exhausted patients it is not best to restrict the diet too much. In young and robust subjects the administration will proceed better if they have been fasting for 6 or 8 hours, but in weak patients it is best not to allow them to remain long without food. If the administration is set for the early morning hours, a little beef tea, soup or milk should be given during the night. When the circulation is particularly weak an enema of beef tea and brandy should be given half an hour before the administration. The rectal, subcutaneous, or intravenous injection of normal salt solution may be advisable or necessary. Preliminary rectal feeding may be necessary in some cases. Some surgeons wash out the stomach before abdominal section for obstruction, or previous to operations for appendicitis.

Cushing recommends feeding with sterilized liquid food and water for several days in preparation for extensive operations on the stomach and intestines in order to lessen the liability to after infection.

Careful disinfection of the mouth and pharynx previous to the administration is recommended as a preventive of post-operative lung complications.

Bowels. It is important that the bowels should be evacuated before the administration, and in certain subjects and operations it is very necessary. Where the operation does not involve the abdominal or pelvic regions a saline purgative given the morning before operation will be sufficient. In abdominal or pelvic operations a free purgative may be given 24 or 36 hours before the administration, and an enema or colonic flushing the morning of the operation. Robust subjects may be purged freely with benefit, but weak and debilitated persons should not be given hydragogue cathartics before operation.

Bladder. The bladder should always be emptied immediately before the administration, especially in young subjects and when nitrous oxide gas is to be employed.

Medicine. The local application of *cocaine* solution to the nose and throat to prevent irritation, cough, holding the breath, and reflex syncope has been practised, and while these conditions can be, in a measure, controlled by this means, the method is objectionable because of the danger of cocaine poisoning. The importance of such applications is lessened by the doubt of the

possibility of the occurrence of fatal syncope from the irritative effect of chloroform.

Alcohol has often been given by the mouth as a general stimulant before operations. Its use in this way is objectionable as it is apt to interfere with the induction of anæsthesia. As a preliminary routine measure it should be discouraged.

Strychnia. The hypodermic administration of strychnia previous to the anæsthesia has been recommended and is a good general practice in debilitated subjects, especially when there is a weak heart. From one-thirtieth to one-twenty-fifth of a grain may be given half an hour before the administration.

Morphine and atropine. Nussbaum, as early as 1863, injected morphia during anæsthesia to relieve after-pain and discomfort. In 1861 Pitha reported a successful anæsthesia with belladonna and chloroform in a patient who had resisted chloroform alone. Labbé and Guyon (about 1872) are said to be the first who used morphine before the administration with the idea of enhancing the action of chloroform.

This so-called *mixed* method of anæsthesia has been more or less employed up to the present time. There is still much difference of opinion as to its relative merits and demerits.

Kappeler, who used mixed anæsthesia extensively, concluded that the anæsthesia is quieter, the stage of excitement shorter, "tolerance" is acquired with less muscular disturbance, asphyxial symptoms are less marked, and vomiting is more frequent than without morphine. He injects the morphine about 20 or 30 minutes before the inhalation. Demarquay thought morphine contraindicated in weak subjects. Wyeth recommends morphine with chloroform to stimulate the heart and quiet the patient.

Morphine, in properly selected cases, especially in connection with the administration of chloroform, gives good results. The dose should be from one-sixth to one-fourth of a grain, given from 20 to 30 minutes before the administration of the anæsthetic. The previous habits of the patient in regard to drugs of this nature should be ascertained, bearing in mind that the habitual use of morphine renders the patient more susceptible to the action of anæsthetics, especially of chloroform. Morphine has been used in connection with cerebral surgery with good effect, but the difficulty of estimating its effects in this class of cases

has induced most operators to discourage its use. In cases in which it is difficult to secure the usual degree of muscular relaxation during anæsthesia morphine will prove of benefit.

When morphine has been given as little of the anæsthetic should be used as possible. The corneal reflex should be preserved, and an analgesic rather than an anæsthetic state should be aimed at. There is not so much danger in an incomplete state of anæsthesia where morphine has been used as where it has not.

Jullard advised the use of morphine before etherization. He recommends the previous use of the drug in order to ascertain the susceptibility of the patient. Kappeler states that he had many failures and more excitement when using morphine with ether.

Dastre and others used the combination of morphine and atropine in order to lessen the liability of cardiac inhibition. Blake uses atropine to diminish secretion and to stimulate respiration in ether narcosis. Reinhard uses both drugs in ether narcosis to inhibit hypersecretion of mucus, giving the injection an hour before the administration. Braun believes that a sufficient dose of atropine to affect the amount of mucus would be dangerous. Becker condemns the use of atropine. He thinks the secretion of mucus can be reduced by adding 20 drops of oleum pumilionis (one of the turpentine oils). The use of atropine in sufficient quantity to affect the secretion of mucus would in most patients increase the danger of anæsthesia. A dose of one one-hundred and fiftieth of a grain in conjunction with morphine does not appear to be objectionable, nor does it appear to have any special advantage unless it may be in certain patients, to offset the action of morphine in adding to the after-effects of the anæsthetic.

Mixed narcosis while of undoubted advantage has also dangers. If care is not exercised in the amount of anæsthetic given the patient may pass into too deep narcosis before the administrator is aware of it. Very little anæsthetic may be necessary to produce deep anæsthesia. It is well for the administrator to inform himself as to whether the patient has had morphine before he begins the administration.

Physical examination. It is not uncommon for the administrator to see his patient for the first time just as the adminis-

tration is about to begin. He is thus afforded no opportunity to recognize any physical condition which might modify the manner or extent of the administration. The objection is offered that questioning and examination of the patients unduly alarms and excites them, but such a result is more often due to lack of tact in such an investigation rather than to the examination itself. Generally patients will feel reassured when such a course is properly pursued.

General condition. The general appearance and bearing of the patient is to be noted. The presence or absence of nervousness, excitement, or hysterical manifestations is to be observed. The character of the subject's movements if he walks to the operating table, the position he assumes on the table, the tendency to assume a propped-up position such as would be natural in emphysema, chronic pneumonia, cardiac lesions, etc., may all be noted. The general condition of nutrition, the apparent age, the general physique, should be observed. Robust, young persons may give some trouble. Fat, flabby, alcoholic subjects may be difficult to anæsthetize. Florid subjects will show a marked degree of cyanosis under such an anæsthetic as nitrous oxide gas.

Physical examination of the chest. This should always be made, particularly of the heart, and of the whole chest if difficulty in respiration is observed. Limitations of the respiratory capacity from diseases of the lungs or pleuræ should be looked for. Stenosis or obstruction of any part of the respiratory tract may be noted by causing the patient to respire deeply. The heart should be palpated for enlargement or misplacement, irregularity, etc., and the stethoscope should be used to detect murmurs, irregular action, and especially the character of the first and second sounds and their relative intensity as indicating the presence or absence of muscular disease. The condition of the arteries should be noted as to the presence or absence of sclerosis or atheroma. The abdomen should be inspected and palpated for any condition interfering with abdominal respiration and the action of the diaphragm. The reaction of the pupils to light should be observed so that any peculiarity in this respect may not be attributed to the anæsthetic. The nose, mouth, and throat should be inspected relative to obstruction of the nares, artificial teeth, plates, loose teeth, quids of tobacco, loose tartar, and in children, pieces of

candy which may be given by some well-meaning relative just before the administration.

Temperature of the room. The temperature of the room should be about 70 degrees F. and the air should be comparatively dry. Warm temperature favors vaporization and elimination. Low temperature has the opposite effect. It may be difficult to anæsthetize in low temperature. Richardson believed that syncope and pulmonary œdema were more frequent under chloroform where the air was charged with moisture.

Ventilation. The room should be well ventilated and free from draughts. In small, badly ventilated rooms lighted by open, artificial lights special difficulty may arise in administering chloroform (*vide* p. 144).

Clothing of patient. For the administration of all anæsthetics the clothing of the patient should be warm and loose. For the administration of nitrous oxide gas it is necessary to see that nothing constricts the neck, chest, or abdomen. Collars should be removed, neck-bands loosened, waists unhooked, corsets unfastened, belts removed. These precautions are often neglected because of the trouble and of the short duration and relative safety of this anæsthetic, but they should never be neglected.

With chloroform and ether there is more or less reduction of body temperature during anæsthesia, and this is often added to by carelessness in properly dressing the patient or in keeping him properly covered during the anæsthesia, or by covering large areas of the surface of the body with towels wet with moist antiseptic solution. The patient should be dressed in warm underclothing, warm stockings, and should be kept, whenever possible, covered with warm blankets. In special cases hot water bottles should be in readiness, or a hot water bed or table may be used.

Posture during induction. As a rule it is best to induce anæsthesia with the patient in the dorsal position with a pillow under the head and none under the shoulders. If the subject suffers from bronchitis, asthma, emphysema or other causes of difficult breathing it may be necessary to have a pillow under the shoulders, at least during the induction. The head should be kept in line with the body. In administering nitrous oxide

gas in the sitting position it is important to keep the head in line with the body, and to prevent the patient from throwing the head too far backwards.

The induction of chloroform anæsthesia should not be attempted in the sitting position if possible to avoid it. The lateral position may be used for the induction if advisable.

Moving of patients. It is best to anæsthetize the patient on the table upon which the operation is to be performed if possible, and not to move him more than is necessary. Statistics show that many of the difficulties and dangers arising during anæsthesia are incident to moving the patient or changing the position during anæsthesia. In those cases where it is necessary to move the patient after anæsthesia has been induced he should be fully anæsthetized and kept so while being moved as vomiting or spasm is more likely to occur if the patient is moved under light anæsthesia.

Appliances and remedies. Before beginning the administration certain appliances and remedies should be within easy reach in case of necessity. A mouth gag may be necessary to keep the jaws apart (Figs. 3, 4, 5, 6, 7), or if difficulty is experienced in separating the jaws some form of mouth opener is necessary (Fig. 8). A tongue forceps for drawing forward or making traction on the tongue should be at hand (Figs. 9, 10), or an ordinary artery forceps may be used. Mouth props for separating the teeth are at times necessary (Figs. 11, 12). A basin should be at hand in case of vomiting, and a couple of towels to be used for keeping the mouth, face, and pillow free from mucus.

Instruments for the performance of tracheotomy should be at hand. In hospital practice there should be appliances for lung inflation, the introduction of saline solution, and for the administration of oxygen gas

Strychnia, digitaline, ammonia, ether, atropine, alcohol, whisky for hypodermic injection should be at hand, nitrite of amyl for inhalation may be useful.

Aseptic precautions. All apparatus used by the administrator should be kept as nearly aseptic as possible, and the administrator should be careful to thoroughly clean his hands and nails. In some cases, such as surgery of the face, head, nose, mouth, throat, neck, or shoulders, all appliances used by the

administrator should be sterilized, and the administrator should be personally as careful as the operator in this regard.

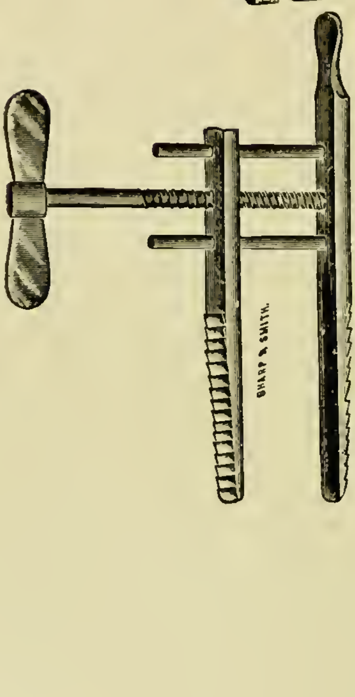


Fig. 3.—Westmoreland's Mouth Gag.

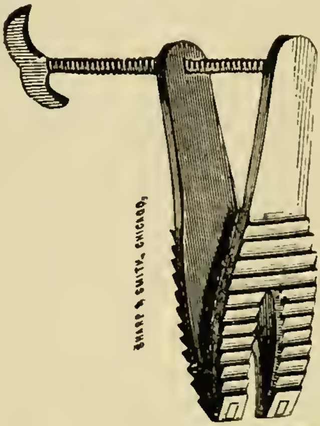


Fig. 4.—Rozier's Mouth Gag.

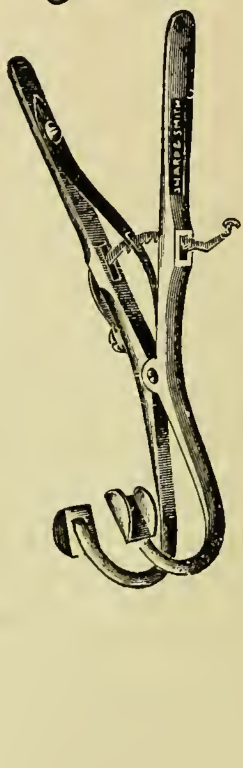


Fig. 5.—Denhart's Gag.

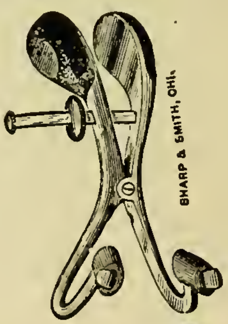


Fig. 6.—Mason's Gag.

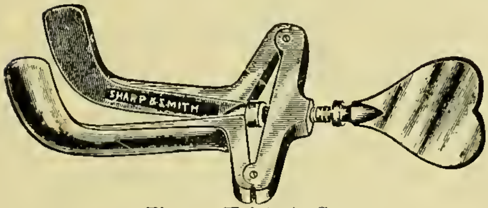
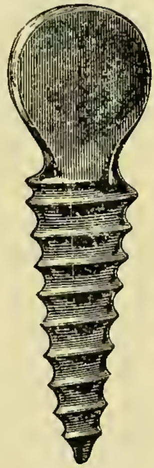


Fig. 7.—Heister's Gag.



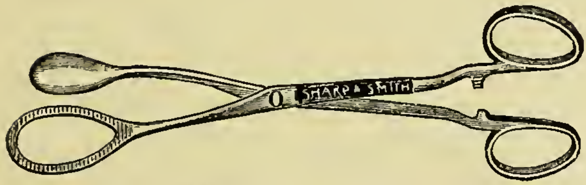


Fig. 9.—Mathieu's Tongue Forceps.

Fig. 8.—Plain Oral Screw.

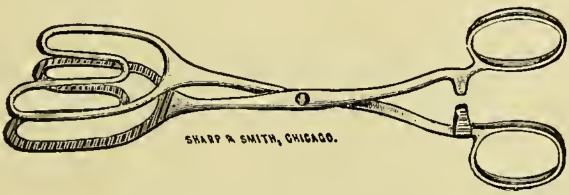


Fig. 10.—Houze's Tongue Forceps.

Fig. 11.—Daintree's Adjustable Mouth Prop.

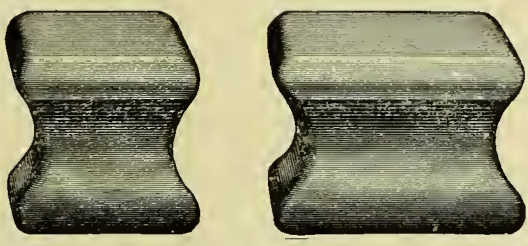


Fig. 12.—Soft Rubber Bite-Block (White Dent. Co.)

CHAPTER VII.

POSTURE DURING ANÆSTHESIA.

The posture of the patient during anæsthesia is determined by the nature of the operation, the anæsthetic to be used, and the general condition of the patient. Faulty positions are likely to increase the danger rate of anæsthetics from complications during anæsthesia and from after-effects. They also interfere with the performance of the operation.

Respiratory difficulties may arise from positions favoring the accumulation of mucus, saliva, blood, etc., in the fauces, as in the semi-recumbent position. Flexion of the head produces obstructive stertor. Complete extension of the head may favor the entry of foreign substances into the larynx, producing attempts at coughing, swallowing, etc. The prone or latero-prone position may interfere with the expansion of the lung and cause asphyxia. The dorsal position may not be possible if there is much pressure on the diaphragm from below. In diseases of the lungs or pleuræ the lateral position with the patient on the sound side may be dangerous. In fat, elderly people, and in dyspnœic subjects the lithotomy position may produce difficulty with respiration.

Difficulties with the circulation are not usually due to posture except as they may occur secondarily to respiratory disturbance from posture. Chloroform and its congeners are generally supposed to favor primary syncope where the sitting position is assumed, and while this danger is probably over-rated, provided the respiration be watched and the anæsthesia be not too profound or prolonged, it is best not to give chloroform in the sitting position if it can be avoided.

Faulty posture may interfere with the performance of the operation by favoring jerky, irregular respiration, coughing, vomiting, straining, muscular rigidity, etc. After-effects may also be due to faulty positions allowing the passing of mucus, blood, pus, etc., into the larynx, trachea, or stomach.

The extraction of teeth. The sitting position is the usual one. The feet are so disposed that they cannot become entangled in the apparatus or chair, or the heels used as a support to the

Fig. 13-A.—Postures for Anæsthesia. 1.—Dorsal position: face to one side. 2.—Lateral position. 3.—Prone position.

Fig. 13-B.—Postures for Anæsthesia. 4.—Sitting position. 5.—Sitting position; bent forward. 6.—Trendelenburg's position.

body. The head should be in line with the body and as vertical as possible. The head may be lowered after anæsthesia is induced if necessary. When chloroform or the A. C. E. mixture is employed the dorsal position should be used.

Operations about the mouth, nose, pharynx, face, or jaws. Any of the various positions ordinarily in use may be employed for these operations. When possible the posture should be such as to allow of the free escape of blood from the mouth. The head should be kept in line with the body. The anæsthesia should not be so profound as to completely abolish the laryngeal and pharyngeal reflexes. Small sponges attached to holders

should be at hand to keep the mouth and throat free from blood, especially if the dorsal position is used. The dorsal position with the head extended obstructs and interferes with coughing and swallowing and tends to increase hæmorrhage. The lateral position is best for the administrator, though in some cases the operator prefers the dorso-lateral. The semi-recumbent or "propped-up" position, with or without extension of the head, is a good one for the operator in operations on the tongue, jaws etc., but is not adapted to maintaining an even and unembarrassed form of anæsthesia. The sitting position is very convenient for rhinological operations. There is no risk in using gas or ether, or the ether-chloroform sequence, in this position. Chloroform alone should not be used with the sitting position unless necessary—as in the removal of laryngeal growths in children.

The bent-forward position is adapted to the removal of post-nasal adenoids. Ether or nitrous oxide-ether sequence may be used with the dorsal or sitting position, and the patient tilted forward for the operation.

The Trendelenburg posture may be used for these operations. It draws blood away from the larynx, but favors hæmorrhage. It is used by some surgeons for hare-lip and cleft-palate operations, also for operations on the naso-pharynx. The lateral and dorso-lateral positions are adapted for operations on the lips and cheeks, jaws, antrum, etc. For operations on the tongue the lateral, latero-prone, or the semi-recumbent positions are mostly used. For removal of the tonsils Hewitt recommends the dorsal position with nitrous oxide-ether, or A. C. E.-ether sequence, and the patient is placed in the sitting position for operation, or the sitting position may be used altogether. In nasal operations the dorsal, lateral, dorso-lateral, or sitting position may be used.

Operations on the larynx and trachea. The dorsal position with the shoulders slightly raised and the head somewhat extended, or the Trendelenburg positions, should be used. For intra-laryngeal operations, when done under general anæsthesia, chloroform should be used in the dorsal position, and the patient then placed in a chair with the head slightly extended.

For operations on the neck the dorsal position with the shoulders slightly raised is preferable.

For operations on the brain the dorsal or lateral positions are

best. For operations on the spinal cord the prone or latero-prone position is convenient but may favor asphyxial complications.

For ophthalmic operations the dorsal or semi-recumbent positions are generally used.

For operations on the chest walls, pleura or lung the position should be such as not to interfere with the expansion of the healthy lung. The prone or semi-prone position is likely to interfere with the respiration and should not be adopted unless necessary. The anæsthesia should be induced in the most favorable position, and watch kept for unfavorable effects following change in position. Recent cases in which the lung has not had time to accommodate itself to the changed conditions are most likely to cause trouble. Pleuritic effusions may be aspirated with the patient in the semi-recumbent, dorsal, or sitting position.

Abdominal operations are adapted, as a rule, to the Trendelenburg posture. The head should be kept in line with the body, or turned very slightly to one side. Obstructed breathing from spasm of the masseters or from flexion of the head may cause active movements of the diaphragm which interfere with the operation. The Trendelenburg position may be contraindicated in cases of great abdominal distention, at least during the early part of the operation. The dorsal position is best adapted to some cases. Bloodgood thinks the Trendelenburg position lessens the dangers of lung complications in cases where from the nature of the operation, disease, or the patient's condition, lung complications are to be feared. This position, as with the low position of the head (Roser's position), undoubtedly tends to prevent the passage of secretions, blood or pus, or foreign bodies, into the respiratory tract.

In operations on the kidney the latero-prone or prone position is used.

In genito-urinary operations, rectal operations, gynæcological operations by the vaginal route, obstetrical operations, etc., the lateral, dorsal, or lithotomy positions will be used as necessary.

CHAPTER VIII.

NITROUS OXIDE.

Nitrogen monoxide, protoxide of nitrogen, nitrous oxide. "laughing gas," has a cheminal formula of N_2O. It was first prepared by Priestley about 1772 or 1776. It is a colorless, transparent, feebly refractive gas with a sweetish odor and taste. Its sp. gr. is 1.527. When pure it is devoid of irritant properties. Water at 0°C. dissolves a little more than its own volume of the gas, the solubility diminishing as the temperature of the water increases. Nitrous oxide gas was first liquefied by Faraday in 1823. Liquefaction takes place under a pressure of 30 atmospheres at 0°C. The resultant liquid is colorless, very mobile body with a sp. gr. of .9369, which commercially is obtained in metal cylinders furnishing 100, 250, 450 gallons of gas according to capacity. The pressure in these cylinders is said to sometimes reach nearly 1,000 pounds to the square inch. The cylinders are subjected to a test pressure of 3,000 pounds to the square inch. Seven and one-half ounces of liquid nitrous oxide will furnish about 25 gallons of gas. The gas is usually pure, but is said to sometimes contain other oxides of nitrogen and chlorine. It is stored for use in gas bags holding about eight gallons, or in gasometers (Figs. 14, 15). The intense cold produced by the conversion of the liquid into gas may produce solidification around the outlet of the interior of the cylinder and interfere with the proper working except when they are constructed so as to avoid this.

Nitrous oxide gas is not easily decomposed, a considerable temperature being necessary to split it into component elements.

Physiological effects and action. Properly administered nitrous oxide gas can be respired without special discomfort or danger up to a certain point. In administration the gas is forced, and the stage of excitement is very brief. The time consumed in producing deep anæsthesia with pure gas and care in excluding air will vary from 20 seconds to 2 minutes, according to the age and constitution of the subject. The length of time which the anæsthetic state will last from a single inhalation period will vary from 15 seconds to 45 seconds. This is

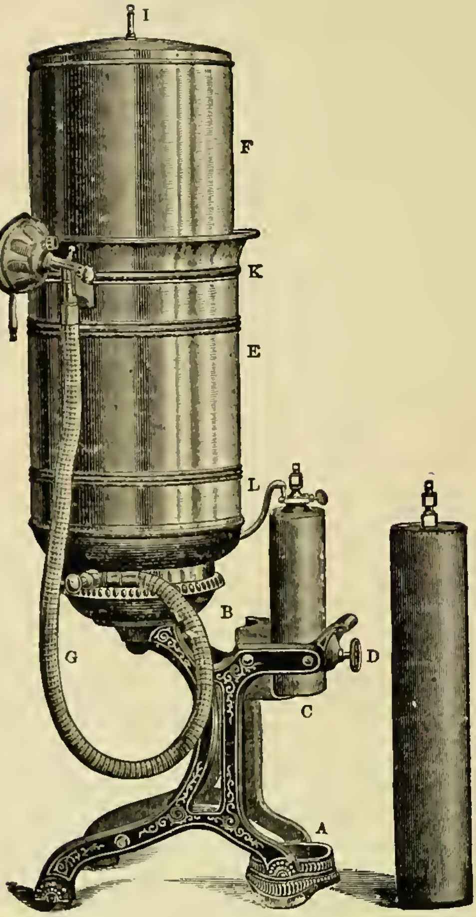


Fig. 14.—Gasometer (White Dent. Co.)

Fig. 14. The socket (A) of the stand is for large cylinders. The reversible clamp (B) fits the large cylinders on one side, and on the other the small cylinders. The side which fits small cylinders has a flange (C) on which sits the cylinder. A set-screw (D) holds the cylinder firmly in position. The reservoir (E) is filled with water to the bead (K).

At the bottom of the reservoir, where the inhaler tubing is attached, is a piston valve (G), placed there for absolute security against waste when operations are suspended with the receiver full of gas. At the opposite side (not seen in cut) is a pipe to which the cylinder yoke is connected by means of rubber tubing (L). Near the top of the reservoir is a wooden fork (H), to support the inhaler when not in use. The bell (F) works on the guide-rod (I).

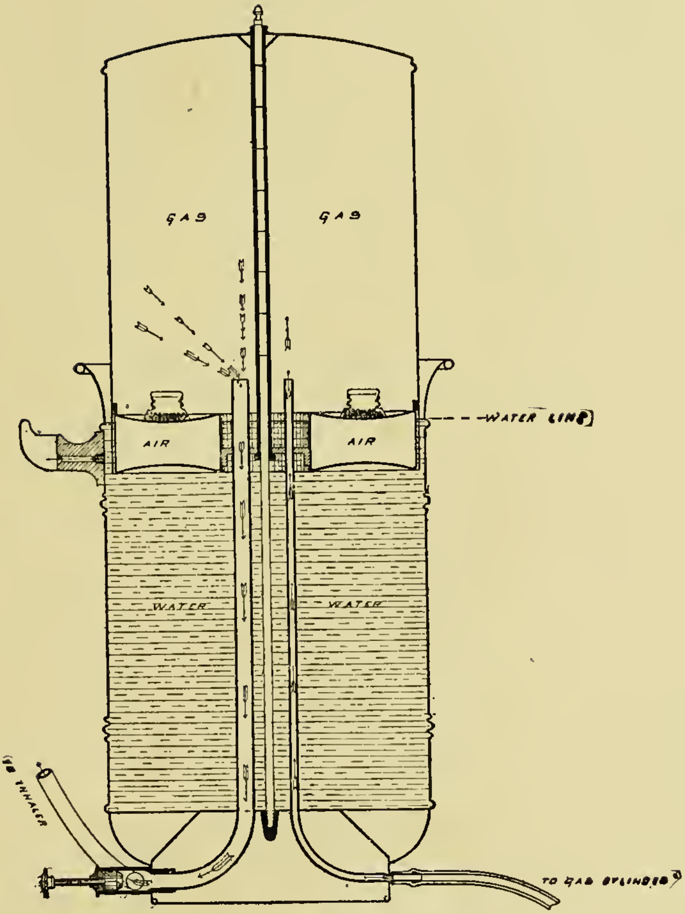


Fig. 15.—Diagram. of White Dent. Co.'s Gasometer.

known as the period of *available anæsthesia* in dental practice. Return to consciousness is very abrupt, often sufficiently so to surprise the subject in attitudes quite unusual to him.

Nitrous oxide narcosis is obtained so quickly that it is difficult to arrange its manifestations into groups. The initial sensations are usually agreeable and exhilarating. There is subjective dizziness, noises in the ears, tingling and loss of body sensation. Illusions are present and may result in mental exhilaration or depression, or in pugnaciousness. Generally unconsciousness is

reached before the subject can speak. There is an irresistible desire to inhale deeply, and the respirations are deeper and quicker than normal. The pulse is fuller and more rapid than usual. As unconsciousness is reached disturbed psychical conditions may arise, especially if the subject be disturbed, roughly handled, or if the operation be begun too early. He may shout or may exhibit co-ordinate or inco-ordinate movements. Dreams may occur, pleasant or unpleasant,—the latter are said to occur more often under the gas alone than when it is combined with oxygen. The respiration is quick and deeper than normal, and the pulse is still full but grows more rapid and may be from 110 to 160 per minute. The conjunctivæ are sensitive and the pupils gradually dilate. The eyelids twitch and separate showing the eye-ball and giving the eyes a protruded appearance. The skin, which first shows pallor, becomes, in florid persons, dusky and livid, or deeply cyanosed. The jaws become set. The respiration which has fairly well maintained its rhythm now becomes arrhythmical, showing that the subject is fully anæsthetized, a peculiar stertor from intermittent elevations of the larynx is manifested. Deep stertor may be present, and clonic spasms of the thoracic and abdominal muscles may occur. Stertor may be absent and irregularity of respiration may be caused by these muscular spasms. Rarely the respiration becomes feeble with prolonged stridulous expiration. These manifestations show that the administration has proceeded far enough. The extremities may or may not remain relaxed. Clonic contractions of various groups of muscles may occur, and tonic contractions of the muscles of the neck or back are sometimes seen even to the condition of opisthotonos. Micturition and defecation are not uncommon. In deep anæsthesia the superficial plantar reflex is lost, but the deep patellar reflex is not. The pupils are usually widely dilated but may not be or may even be contracted. Post-anæsthesial dilatation of the pupils may occur. The corneal reflex is usually maintained. The conjunctival reflex may disappear and is not a reliable guide to the state of anæsthesia.

With the withdrawal of the anæsthetic the respiration rapidly assumes its usual rhythm and the pulse drops suddenly in rate, the subject rapidly returning to consciousness. The pulse may afterwards be rapid from mental conditions or from pain.

Among the recognized after-effects of nitrous oxide anæsthesia are headache, dizziness, nausea, vomiting, faintness, hysterical attacks, hallucinations, stupor, catalepsy, hemiplegia, and even insanity. Temporary glycosuria, diabetes, and retinal hæmorrhage have been known to occur.

Lethal doses of nitrous oxide gas produce death by asphyxiation. The heart beat may continue for several minutes after respiration ceases. The latter is said to be due to muscular spasm. The right heart cavities are found full of blood and the left cavities relatively empty.

It was formerly thought that the phenomena attending the administration of nitrous oxide gas were all asphyxial or anoxæmic in character, depending on want of oxygen, but the observations of E. Andrews, and of Paul Bert showed that anæsthesia could be produced without asphyxial conditions by the conjoined use of nitrous oxide gas and oxygen. Nitrous oxide must therefore possess some anæsthetic properties aside from its asphyxial powers. On the other hand the phenomena can not all be special or non-anoxæmic because by the addition of oxygen the stertor, epileptiform movements, and the cyanosis may be obviated without interfering with anæsthesia.

The anæsthetic property of nitrous oxide is thought by some to be due to a deoxidizing action on the usual process of oxidization occurring in nerve cells, and similar to that of other anæsthetics.

The blood changes occurring during anæthesia with gas are not thoroughly understood. The gas is very soluble in blood, and there is a great reduction in the oxygen in the blood. (Experiments have shown that after breathing nitrous oxide for a period of 105 seconds that there is a reduction of the oxygen of the blood from 21 to 5.2 vol. per cent.) The blood pressure is raised, and later falls with the appearance of respiratory embarrassment. There is contraction of the renal vessels and diminution in the secretion of urine. Slight albuminuria may occur with complete anæsthesia.

THE ADMINISTRATION.

The universal employment of nitrous oxide gas in dental surgery attests the fact that with very few exceptions this agent is the best for use in dental practice. In operations which re-

quire not more than a few seconds no other anæsthetic can compare with nitrous oxide either in safety, efficiency, or in convenience. Colton originally urged the exclusion of air in nitrous oxide anæsthesia, and the advisability of administration with an inhaler fitted with inspiratory and expiratory valves. He afterward showed the advisability of allowing air to be breathed in connection with the gas in cases where a little more time was necessary than in ordinary dental operations, and devised inhalers for use under such circumstances.

Andrews' observations regarding the administration of oxygen and gas, and Paul Bert's researches along this line brought about the conclusions now recognized, that by the use of certain amounts of atmospheric air a better form of anæsthesia can be obtained than with pure gas, especially for occasions demanding one or two minutes of anæsthesia, and that with oxygen and gas a still more satisfactory form of anæsthesia may be obtained. The more complicated apparatus, and the greater skill and experience necessary to obtain satisfactory results with these methods have restricted their use, and the pure nitrous oxide anæsthesia remains the most universal method of administration.

The various methods of administration which may be employed are: The administration of pure nitrous oxide; of definite quantities of nitrous oxide and air; of nitrous oxide and indefinite quantities of air; of definite quantities of nitrous oxide and oxygen at ordinary atmospheric pressure; of the same under increased atmospheric pressure (Paul Bert's system); of nitrous oxide and varying quantities of oxygen at ordinary atmospheric pressure.

For the administration of pure nitrous oxide gas for ordinary dental operations the patient should be seated in an operating chair in a comfortable position. Care should be taken that the subject's legs cannot become entangled in the chair or apparatus in case of muscular contractions, nor a purchase be obtained for the feet should opisthotonos occur. The head should be in line with the body, and as vertical as possible. If a vertical position of the head is not satisfactory to the operator, then it should be kept in that position during the induction of anæsthesia by a cushion which can be quickly removed as full anæsthesia is reached.

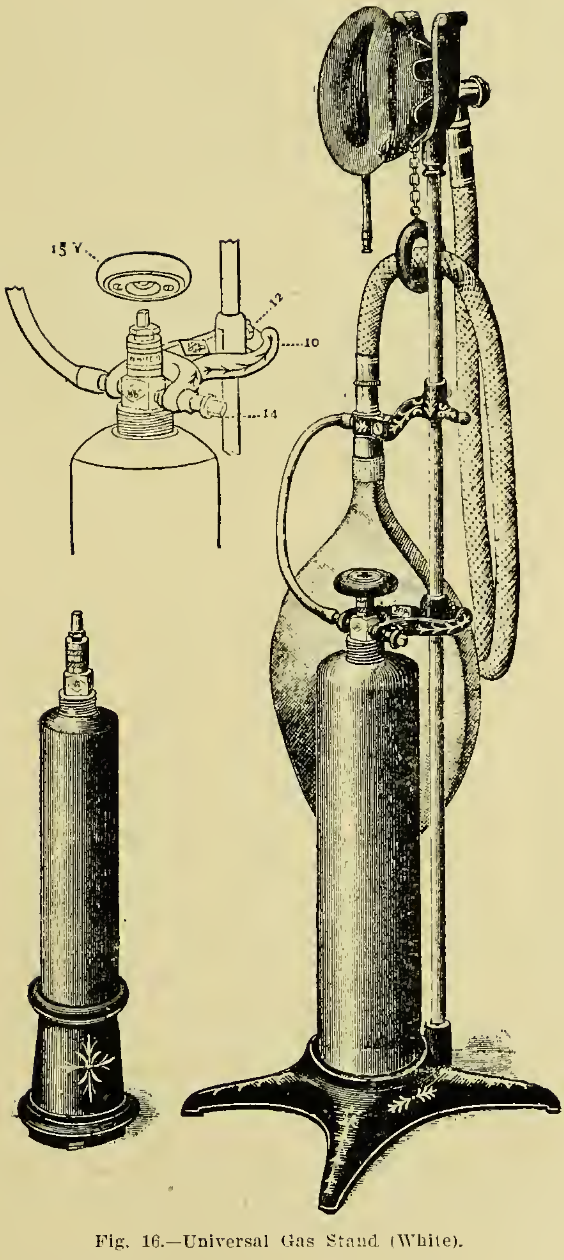


Fig. 16.—Universal Gas Stand (White).

Fig. 16. The base is of iron, with a coned socket for the reception of the cylinders. The upright carries a yoke connection for the valve of the cylinder, an arm for the support of the gas-bag, and a wood fork at the top for holding the inhaler when not in use. Attached to the fork by means of a chain is a wood ring for the support of the inhaler tubing. The base is heavy to assure solidity and firmness on the floor. The coned socket provides for Medium and Large Cylinders, the latter sitting in the upper part and the former passing down to the bottom. For the Small Cylinders a pedestal casting is provided which sits in the coned socket, with catches to hold it firmly to the base.

The yoke connection, 10, has a short up and down swing to accommodate itself to the cylinder neck. It is also adjustable upon the upright. As shown it is in position for the Small and Medium Cylinders. For the Large Cylinders it can be raised by loosening the set-screw 12 (a countersunk spot will be found on the rod to receive the set-screw in the new position). The cylinder is held securely in the yoke by tightening the screw 14. Be sure there is a leather washer on the yoke nipple, to make a tight joint between the yoke connection and the cylinder. The wood wheel-key 15Y operates both the yoke screw 14 and the valve of the cylinder. A quarter turn releases the yoke screw.

In short operations it may be desirable to introduce a bite-block, or mouth-prop, before anæsthetizing in order to avoid delay in opening the mouth after anæsthesia is produced. In long operations this may not be desirable. If the block or prop should slip it is probably best to stop the administration and readjust the block. In some cases it may be desirable to introduce a gag before administering gas, in which case it is necessary to be careful to prevent the admission of air along the arms of the gag.

Before beginning the administration be sure that there is a sufficient quantity of gas. Ordinarily not more than six or eight gallons will be needed, and children will usually need but three or four, but it is best to have an ample reserve.

Run some gas through the apparatus (Fig. 16) and fill the bag about two-thirds full of gas and shut off the cylinder valve. See that the valves in the inhaler are working properly. If the patient has a beard, moisten the hair about the mouth before applying the face-piece. Explain to the patient that there is no danger or suffering connected with the administration of gas, and show him how to breathe deeply and regularly through the mouth. Apply the face-piece and see that it fits properly by having the patient respire air in and out through the valves before turning on the gas (Fig. 17), explaining meanwhile to the patient that he is simply breathing air. The regular sound of

the valves will show that the face-piece fits properly (Fig. 18). The pneumatic face-piece is probably the most easily adjusted and satisfactory.

If the face-piece fits properly and the patient is breathing freely the gas should be turned on. The bag at this time should be about two-thirds full, and should be kept nearly full throughout the administration by allowing a small amount of gas to

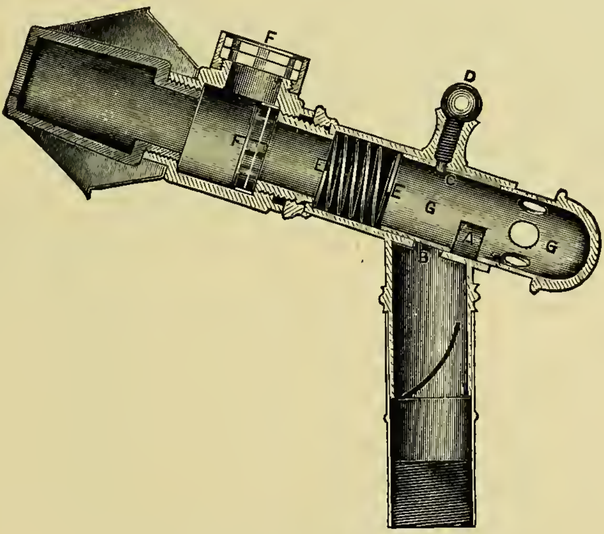


Fig. 17.—Inhaler No. 3. (White Dent. Co.)

Fig. 17. The sectional view shows the internal construction. An opening, B, underneath the body of the Inhaler admits the gas through a similar opening, A, in a sliding tube GG, fitting inside of and projecting beyond the rear portion of the main body. The projecting portion is perforated for the admission of air, and its outer end is closed by a cap. At the inner end of the sliding tube is a coil spring EE, abutting against a shoulder in the body of the Inhaler. This spring holds the sliding tube in the position shown in the cuts, closing the inlet B when the gas is not being used. Pressure on the cap compresses the spring, closes the perforations for the admission of air, and brings the opening A over B, affording a free flow of gas to the mouth-piece through the inhaling valve. The sliding tube is prevented from rotating by the screw-pin D, which works in a slot, C. The inhaling and exhaling valves—the former internal, the latter external—consist of two thin disks of mica, FF, which are inclosed in circular open cages. The inhaling valve is opened in respiration by being drawn against the front of the cage, the exhaling valve being closed by the pressure of the outside air. In expiration both disks are thrown against the further ends of the cages, opening the exhaling and closing the inhaling.

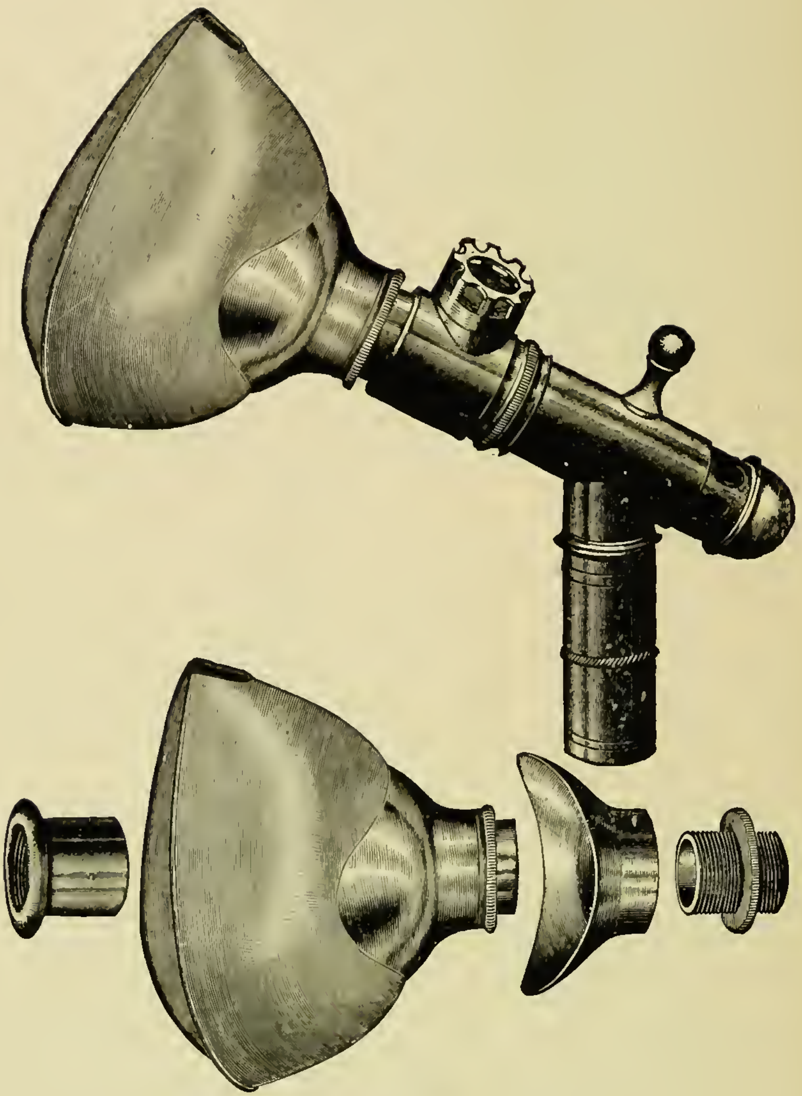


Fig. 18.—No. 3 Inhaler and Flexible Mouthpiece. (White Dent. Co.)

enter from the reservoir, with a slight positive pressure, except in children and weak persons. Excitement should be controlled by increasing the pressure in the bag, as the disturbance will

probably be due to admission of air, which is not likely to occur under higher pressure. A slight amount of air is often of advantage in children and weak people.

There has been considerable argument as to the propriety and advantage of rebreathing of gas, or to-and-fro breathing directly in and out of the bag. Hygienically it is, of course, objectionable, and obviously not admissable in the early stage of administration, but is said to have advantages during the latter part of the inhalation period in that it leads to a longer available period of anæsthesia, and, while taking a little longer to produce complete anæsthesia and being followed by a slower return to consciousness, it produces no bad effects. It would seem, however, that improvements in the technique of administration will practically obviate this somewhat objectionable method.

Unpleasant effects are often due to the operator beginning work too soon, or to his attempting to accomplish too much during a single period of available anæsthesia. The latter is often so short that but a single extraction can be effected while it lasts, though an ordinary operator can usually extract two teeth or roots while the patient is completely unconscious.

The following directions by Turner for anæsthesia for extraction are useful: Food should be limited to good beef-tea taken about two hours before anæsthesia. The patient should not come straight from violent exertion. Undo all tight clothing about throat, chest, waist and abdomen. Seat the patient comfortably, body relaxed, in straight line with head, neither too far back nor depressed, in such a position that with prop in position blood or teeth will pass into floor of mouth. Support head by a rest under the occiput, or nape of neck. Support the head on side for extractions from upper jaw, and support lower jaw for lower teeth. If operator supports lower jaw himself, then press on front of condyle on side operated on, to prevent dislocation. When patient is reviving see that no blood is swallowed or inhaled. If necessary to push head forward, push whole body. Let patient come around quietly. If gas is followed by ether, do not give too much air at first. Patients should lie down for awhile or take it easy for rest of day, as gas causes strain on the heart. Unfit subjects are people with degenerated arteries; fat people; people with heart or pulmonary trouble. The

admission of some air does away with much of the asphyxial strain.

Should the operator require more time than is obtainable by a single period of inhalation, the administrator has several courses open to him. He may reapply the face-piece before consciousness returns, and this is advisable when the patient's head can be maintained in the vertical position, so that blood will flow into the floor of the mouth and not into the throat, and if quickly carried out results in no unpleasant effects; again, he may allow a return to consciousness and repeat the inhalation, though double administration is more often followed by nausea and vomiting when there has intervened an interval of consciousness; he may keep up a continuous inhalation by means of a mouth-tube (Fig. 19), or nose-piece which allows more or less air during inhalation, a method which is said to give satisfactory anæsthesia, but which is more difficult of application and demands more resistance than other methods. McCardie, of Birmingham, uses a tube about the size of an ordinary ovariotomy canula for prolonging nitrous oxide anæsthesia. The gas is briskly passed into the mouth during extractions, the nose being closed by the fingers or by a special clip. The administration is conducted in the ordinary manner by a face-piece till the patient is unconscious. By this method the whole mouth can be cleared of teeth without any pain, except in powerful subjects who require more profound anæsthesia in order to abrogate reflex movements. Gardner highly recommends a method which he has personally experienced, consisting of administering gas through a small nose-cap containing two small metal tubes attached to rubber tubes leading to a gas bag behind the patient's head. The patient usually breathes through the nose, but even if he breathes through the mouth anæsthesia is readily induced. Though there is complete anæsthesia, there is not so marked effect of the drug as there is with the ordinary method, cyanosis being less, pupils not so dilated, the eye often remaining mobile, and the condition being more one of marked drowsiness than one of coma. Again, the operator may administer oxygen with nitrous oxide; or again, he may prolong the anæsthesia by the use of a small quantity of ether, providing the stomach is empty and care be taken to prevent blood from getting into the throat.

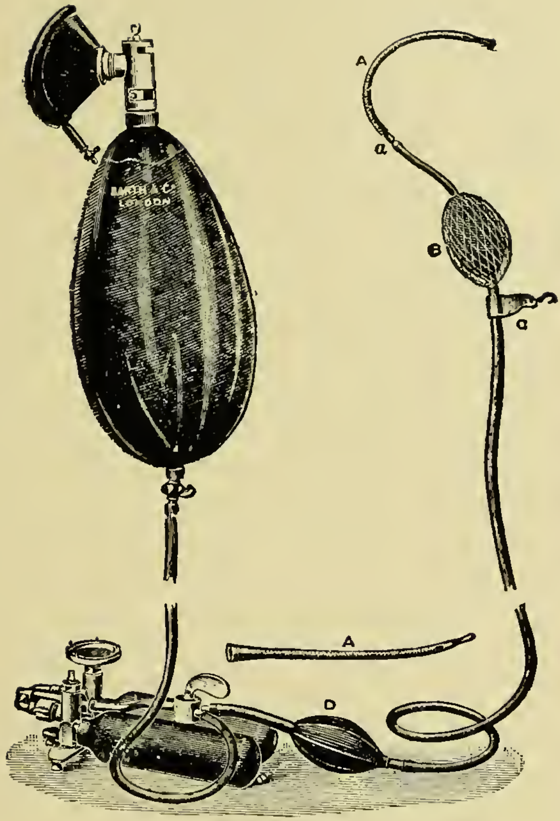


Fig. 19.—Anæsthetic Inhaler (Hillard).

Fig. 19. A method of prolonging nitrous oxide anæsthesia in dental practice by means of an additional gas tube leading from the bottles to a catheter, which is passed through one of the patient's nostrils. (*D—A*). The administration is conducted in the usual way with stop-cock and face-piece until the patient has lost consciousness, then taking the precaution that the ordinary gas bag is full, and choosing the end of an inspiration the face-piece is removed; the nasal tube (*A*) is rapidly passed (this can be done during a single expiration), the face-piece is re-applied, and the pedal stop-cock is turned so that the gas now flows only through the nasal tube. At this stage the inhalation is continued by both nasal tube and face-piece up to full anæsthesia. The face-piece is now finally removed, the operation is begun, and narcosis is maintained by the nasal tube alone. To prevent the return of consciousness, the netted bag (*B*) must be kept fully distended, the gas being supplied at considerable pressure. It is claimed that 10 or 12 teeth can easily be extracted during the available anæsthesia.

Disagreeable after-effects are, of course, more common from the latter method than from a double administration of the gas.

THE DANGERS OF ADMINISTRATION.

The dangers of nitrous oxide anæsthesia arise practically always from primary interference with respiration, due to spasmodic obstructive stertor or to muscular spasm of the thoracic or abdominal muscles. There is marked cyanosis, the eyes are widely open, the eyeballs turned up and the pupils widely dilated, the pulse is usually small and rapid and generally continues for some time after cessation of respiration, but may show early arrest in weak, debilitated persons. Elderly people especially may develop obstructed breathing from engorgement of the tongue. Abnormal conditions of the upper air passages favor respiratory embarrassment. Foreign bodies in the air passages, such as blood, mucus, pus, vomited material, morbid growths, teeth, instruments or material, etc., are sources of danger.

While syncope and faintness are not uncommon as manifestations of the period of returning consciousness, it is doubtful if they occur from primary cardiac failure.

Simultaneous failure of heart and respiration is very rare, but may occur in patients with cardiac, mediastinal, or cardio-pulmonary lesions. In this instance the circulation is not well maintained up to the period of stertor, but becomes feeble early. There is bluish pallor and the respiration is shallow instead of stertorous and irregular.

THE ADMINISTRATION OF DEFINITE QUANTITIES OF NITROUS OXIDE AND AIR.—The admission of indefinite quantities of air at irregular intervals has long been practiced during nitrous oxide anæsthesia with the effect of prolonging the anæsthetic state. Hewitt, of London, experimented with definite quantities of air and nitrous oxide administered by means of a specially constructed gasometer by which any desired percentage of the gases could be administered. He found that anæsthesia could be induced by this means, providing the amount of air did not exceed 30 per cent. With a small amount of air the symptoms were similar to those from the pure gas. The inhalation period increased in direct relation to the raise in the percentage of air. The duration of available anæsthesia was longer than after nitrous oxide alone. With from 3 to 5 per cent. of air convulsive movements

were more marked than with nitrous oxide alone, while with higher amounts of air these phenomena decreased and were absent with 30 per cent. of air. The same was true of lividity and cyanosis. Hewitt explains this on the ground that with no air obstructive stertor cuts short the inhalation of gas before the blood is sufficiently saturated to produce muscular convulsion. Stertor was progressively lessened with increase in air. Reflex movements were less marked than with pure gas. The best general results were with from 14 to 22 per cent. of air. The best mixture for men, was from 14 to 18 per cent. of air, and for women and children, from 18 to 22 per cent. of air.

THE ADMINISTRATION OF NITROUS OXIDE AND INDEFINITE QUANTITIES OF AIR.—Indefinite quantities of air may be administered with nitrous oxide alternately or concurrently. The effects will vary according to the quantity of air admitted. In the alternate administration the administrator anæsthetizes with nitrous oxide in the usual manner until partial or complete narcosis is induced, and then shutting off the gas allows the patient to breathe a few breaths of air and then returns to the nitrous oxide. In this alternate manner the administration proceeds until sufficiently deep anæsthesia is produced for dental operations, or, in general surgery, until the operation is completed. In the concurrent use of air and gas the two are breathed simultaneously, sufficient air being allowed to enter to obviate asphyxial manifestations.

In this country, especially, many variations of this method have been practiced during the last twenty-five years in order to produce satisfactory anæsthesia for more or less lengthy operations. Dr. George Brush, of Brooklyn, employed an inhaler with a sliding air valve, and quite lengthy operations were performed under the anæsthesia thus induced.

For comparatively short operations when absolute muscular relaxation is not an essential this method can be made efficient, but for operations demanding complete muscular relaxation it is not so satisfactory as the use of ether or chloroform.

There are few or no after-effects from this form of administration, and in special cases and subjects it may be used, though it is not always possible to obtain a strictly non-asphyxial form of anæsthesia.

The amount of air admitted may be increased with the length of the anæsthetic stage, the indications being obtained by close attention to the patient's condition.

The difficulty with this method of administration is to admit enough oxygen to prevent asphyxial symptoms and yet secure enough nitrous oxide to insure complete anæsthesia. This difficulty arises largely from the large percentage of nitrogen in the air. Thus if we admit sufficient air to afford a high enough percentage of oxygen to prevent anoxæmic conditions the displacement of gas will be so great, owing to the amount of nitrogen in the air, that anæsthesia will not be complete.

The administration of nitrous oxide gas and oxygen.—In 1868 Dr. E. Andrews, of Chicago, employed oxygen in connection with nitrous oxide gas and produced a non-asphyxial form of anæsthesia. But little attention was paid to his observations and this method of anæsthetization attracted small notice until Paul Bert published his experiments along the same line about 1878. Bert concluded that satisfactory anæsthesia by this means could only be effected by increasing the atmospheric pressure, but the observations of other experimenters have shown that increased pressure is not necessary for anæsthesia under this method, although it may increase the effects. In Bert's method the patient, administrator and bag were placed in an air-tight metal compartment, and the gas with 15 per cent. of oxygen was administered under a pressure of 89.5 cm. M. Martin modified this by employing 12 per cent. of oxygen and a pressume of 110 cm.

Under this method respiratory disturbance, cardiac irregularity, and asphyxia were slight, but it is not clear that this system has great advantage over other methods of administration. The apparatus is expensive and cumbersome, and the increased pressure a source of more or less discomfort to the operator and assistants.

Hewitt has experimented with the administration of nitrous oxide with definite amounts of oxygen, and while this system has disadvantages, being difficult of application, varying requirements for individual subjects, and impossibility of varying the percentage of oxygen according to the indications arising during the administration, which interfere with its practical utility, nev-

ertheless the effects of certain known percentages of oxygen afford us a knowledge upon which basis we can predicate in the administration of oxygen with nitrous oxide gas for prolonged operations.

Hewitt's deductions are as follows: The inhalation period lengthens as the percentage of oxygen rises; deep anæsthesia is obtained even when the amount of oxygen equals that of atmospheric air; the duration of anæsthesia is longer than with nitrous oxide and air; the longest available period of anæsthesia (50.1 seconds) is obtained with 7 per cent. of oxygen; with 6 per cent. and over of oxygen there are no convulsive movements; with 11 per cent. of oxygen there is no lividity; with from 2 to 6 per cent. of oxygen stertor is irregular or is replaced by regular snoring, which becomes less marked with higher percentages of oxygen, and disappears altogether with 20 per cent. of oxygen; phonated sounds are less common with nitrous oxide and oxygen than with nitrous oxide and air; they are likely to occur with very small or with very large percentages of oxygen; reflex and excitement movements obtain with 10 per cent. or more of oxygen and may be pronounced with from 5 to 7 per cent., or in females with from 7 to 9 per cent. of oxygen.

Unquestionably the most successful way of employing nitrous oxide and oxygen is the administration at ordinary atmospheric pressure of nitrous oxide with a varying proportion of oxygen. Up to the present time this method has not been widely used, but with improved apparatus and more general recognition of its advantages in properly selected cases, together with increasing skill in its administration, it will, no doubt, become much more generally employed.

The anæsthesia induced by this method is particularly adapted to the demands of dental operations, the average of the available period of anæsthesia as given by Hewitt being 44 seconds, although it varies greatly. The inhalation period is given as averaging 110.5 seconds.

In general surgery the use of gas and oxygen is somewhat limited. While it is not difficult to maintain unconsciousness, it is not always possible to secure the deep anæsthesia required for many operations, such as plastic operations or rectal or vaginal surgery. For lengthy operations it is a difficult system of an-

æsthesia to maintain, but for slight operations about the mouth, nose or throat it is quite applicable. It is also useful for short, secondary operations or for painful redressing where very temporary anæsthesia is desirable.

The best subjects for this method of anæsthesia are young women, weak, elderly and middle-aged women, and debilitated men of middle life. Young men, robust adults, and alcoholic persons are not good subjects for this method.

The effects of nitrous oxide and oxygen are similar to those of the pure gas, with the difference that the respiratory difficulties of the initial stage are more or less absent. Consciousness is maintained slightly longer than with gas, and the period between this and the establishment of available anæsthesia is also somewhat longer. Excitement may be present, but may be stopped by cutting off the oxygen. The respiration may be deep and rapid and may change suddenly to quiet or imperceptible breathing. It gradually becomes quiet, with slight snoring. When deep anæsthesia is reached the subject appears as if in natural sleep. Stertor is absent unless the quantity of oxygen is too small to be of any benefit. Spasm of the muscles of the chest and abdomen is not present. There is little tendency to congestive obstruction of the upper air passages. The color of the face is pale or florid. Cyanosis is usually absent. The pulse is rapid, but is not so small as under nitrous oxide anæsthesia. According to Broadbent there is lowering of tension from peripheral dilatation. Cardiopathic patients take nitrous oxide and oxygen very well as compared with other anæsthetics. The eyes are usually closed. The eyeballs are fixed and may be turned to one side or the other. Marked dilatation of the pupils is not common. The conjunctival reflex is usually absent, while the corneal reflex is retained except in protracted anæsthesia. Anæsthesia is evidenced by regular breathing, slightly snoring in character; by relaxation of the arms; by loss of conjunctival reflex, and by fixed eyeballs.

In administering nitrous oxide and oxygen the patient should be in a sitting position, with the head in line with the body and not extended. If the recumbent position is necessary, as in general surgery, the lateral position is probably the best, and a flat couch or operating table should be used. The same preliminary

attention should be given to apparatus and patient as in the use of gas alone. Special attention should be given to the fit of the face-piece, as it is even more important in using both agents that the face-piece should fit closely than it is in using gas alone. (Figs. 20-23.)

When the patient is breathing air freely the gas, with a small percentage of oxygen, is turned on. If too much oxygen is used

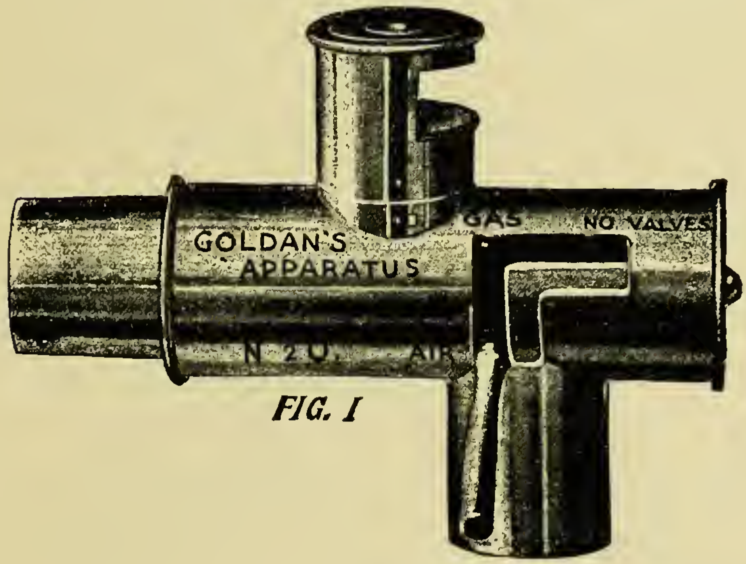


Fig. 20.—Goldan's Stop Cock.

Figs. 20. 21, 22. The gas stop-cock (Fig. 20-I) contains two valves. The inspiratory valve is set in an inner cylindrical tube, which works by a handle through a right-angled slit in an external cylinder supporting the expiratory valve superiorly, and inferiorly giving attachment to the gas-bag for gas alone, or the inverted Y-shaped tube for gas and oxygen. The valves themselves are made of thin sheet hard rubber, and are therefore indestructible. When the handle is turned down to the point indicated by "air" (see Fig. 1 diagrammatic plate, Fig. 21) the gas-bag is closed by means of the obturating function of the inner tube; when the handle is turned upward to the place indicated by "gas" air is excluded and gas is inhaled by means of the inspiratory valve. Expirations of the patient pass out through the expiratory valve; at the same time the inspiratory valve is closed.

When the handle is pushed backward to the place indicated by "no valves" the valves are thrown out of action; the patient then breathes back and forth into the gas-bag. This feature is used only with the gas and ether method.

at first excitement may arise. If pure gas is given at first it may be difficult to modify its effects without giving too much oxygen. After a few seconds the oxygen indicator of the apparatus may be turned to 3 or 4, etc.

In young or anæmic subjects the amount of oxygen may be increased more quickly than in healthy, robust adults.

The gas bags should be kept equally distended. The bag containing the nitrous oxide will, of course, demand more attention than the oxygen bag. Signs of excitement indicate less

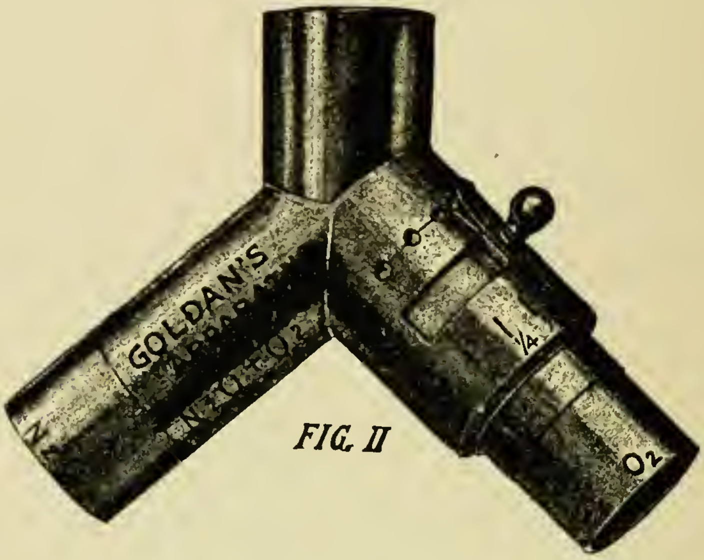


FIG. II

The essential part of the gas and oxygen apparatus is an inverted Y-shaped tube (Fig. 20-II) attaching to the lower part of the valved stopcock. It will be noticed that the right arm of the tubes is somewhat longer, to accommodate a revolving obturator which regulates the quantity of oxygen. This arm of the tube is so constructed that when the obturator is fully open it represents exactly one-half that of the nitrous oxide arm; if so used it would represent exactly 33 1-3 per cent of oxygen. It may be said that anæsthesia is never possible with such a large percentage of this gas. Graduations are accurately marked on the surface of the tube as 1-2, 1-4, 1-8, 1-16, 1-32, representing respectively about 33, 25, 12, 6, and 3 per cent of oxygen; these graduations have always reference to the opposite tube. The surface of the oxygen tube has also small depressions into which the metal spring slips when the oxygen is turned on; this permits the use of the apparatus without taking the attention of the administrator from the patient.

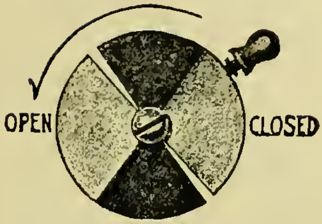


FIG. III

Fig. 20-III shows the obturator, which opens by revolving from right to left. The small opening represents about 6 per cent of oxygen. The vertical arm of the Y is the mixing-chamber for the two gases.

Two separate gas-bags are used, and by this means their respective distention may be more easily seen than with the single bag with septum. From four to six feet of rubber tubing connect the cylinders and gas-bags for transmission of the gases. The cylinders shown are the small portable ones of English manufacture, with foot attachment. Fig. 22 represents the gas and oxygen apparatus complete. There are two cylinders for nitrous oxide and one for oxygen, for the reason that a far greater quantity of nitrous oxide is used than of oxygen. The face-pieces of different sizes may be obtained of rubber, celluloid, or metal, with inflatable rims.

In order to obtain perfect results with nitrous oxide and oxygen particular attention must be given to the following points:

1. The apparatus must be in perfect working order and always tested by the administrator himself.

2. A sufficient supply of both gases at hand.

3. Atmospheric air must be rigidly excluded. In patients with beards the nostrils may be closed; the mouth-tube may be used instead of the face-piece or the beard thoroughly moistened with water.

4. The patient should be prepared as for any surgical anæsthetic.

5. The gas-bags should never be fully inflated, but between one-half and two-thirds full. In this way the pressure of the gases is kept more nearly equal.

6. Oxygen should not be turned on immediately the administration begins, but sufficient nitrous oxide inhaled to replace the oxygen existing in the blood; three to six breaths will be sufficient.

Oxygen should be admitted gradually and in quantity determined entirely by the patient's condition, remembering cyanosis calls for more oxygen; evidences of excitement and returning consciousness meaning that less oxygen is required. In using the gases in long narcosis the taps of especially the nitrous oxide cylinders are apt to freeze, owing to the transition of the gas from the liquid to the gaseous state, the cylinders becoming covered with frost; to avoid this a towel wrung out of boiling water should be placed about the tap, but not about the cylinder itself.

The patient should always be placed upon the operating-table in the position in which the operation is to be performed; any position may be employed, providing it will not interfere with the anæsthesia.

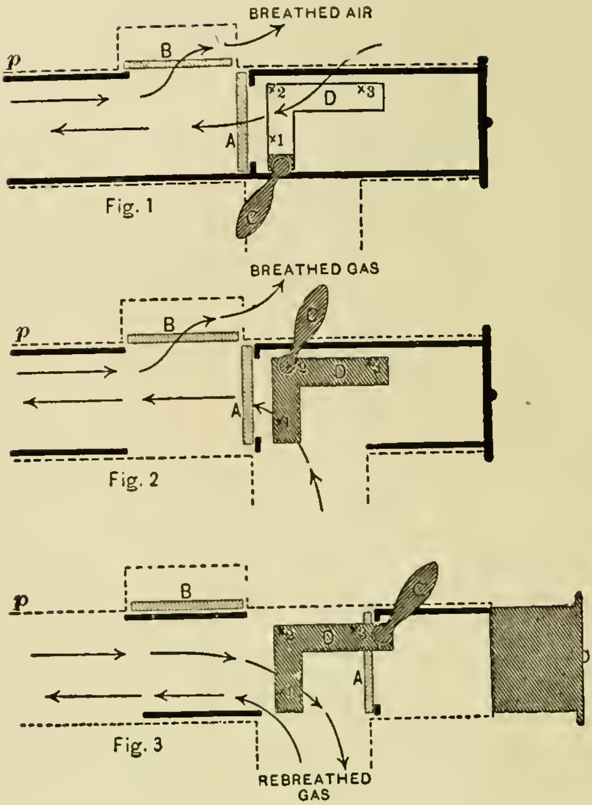


Fig. 21.—Diagram of Goldan's Stop Cock.

Fig. 21. Dotted lines indicate external part of stop-cock, heavy lines and shaded part, internal tube. Arrows indicate direction of inspiration and expiration. The valves are indicated by shaded lines. *A*. Inspiratory valve. *B*. Expiratory valve. *C*. Index handle. *D*. Right-angled slit. *P*. Proximal end of stop-cock, attaching face-piece. *X*. Handle turned down; air breathed. *X*2. Handle turned up; gas breathed. *X*3. Handle turned up and back; gas breathed back and forth into gas-bag.

oxygen. In from twenty to twenty-five seconds the indicator may be brought up to six or seven, which will probably be sufficient for dental operations. In longer surgical operations a progressive increase in the amount of oxygen is generally advisable.

Operative proceedings may begin within from two to three minutes of the application of the face-piece.

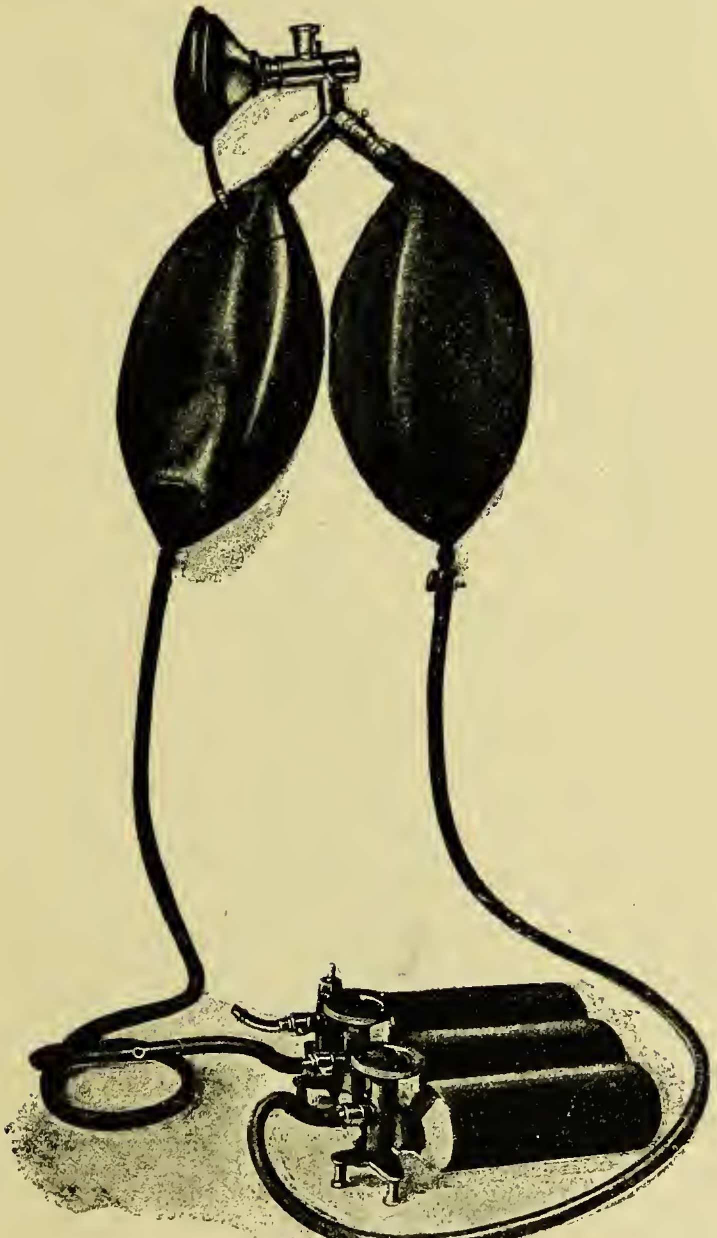


Fig. 22.—Goldan's Apparatus for N_2O and O. (Am. Jour. Med. Sci., June, 1901.)

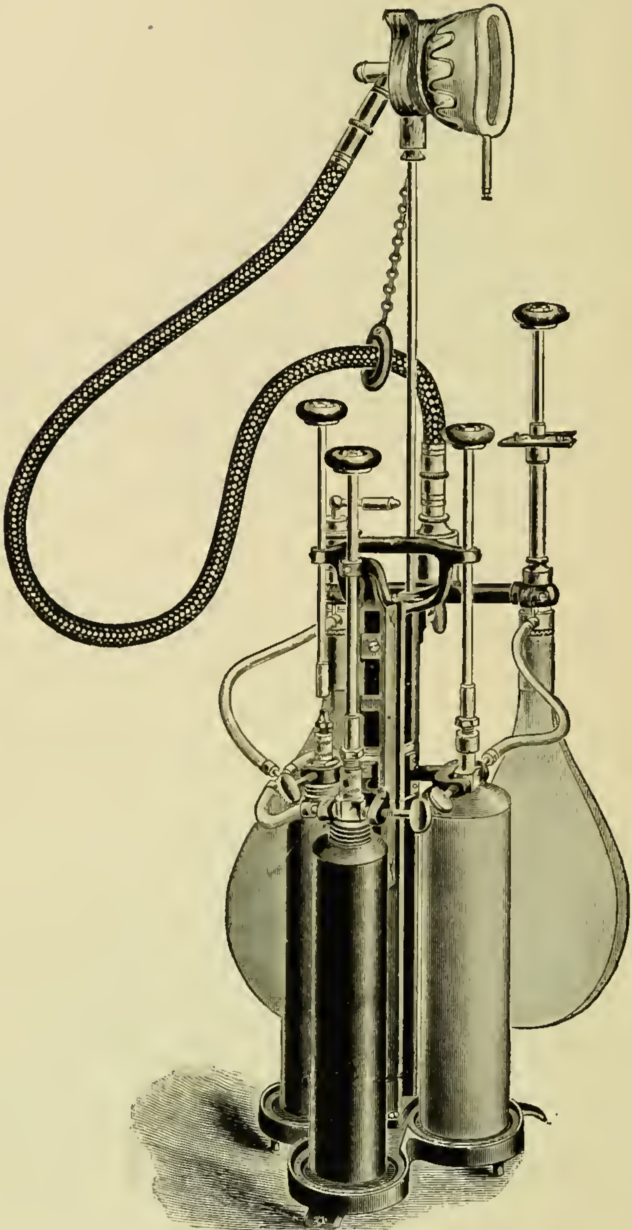


Fig. 23.—Apparatus for N_2O and O (White Dent. Co.).

Fig. 23. One cylinder contains Pure Oxygen.

The other cylinder is filled with Nitrous Oxide.

There are rubber bags, of different colors to avoid confusion; black for Nitrous Oxide and red for Oxygen.

There are keys which open the valves of the cylinders and allow the gas to fill the bags through the tubes.

Another set of valves being closed, the gas remains in the bags. By opening one Nitrous Oxide is admitted to mixing chamber, from which it flows through the covered rubber tube to the Inhaler.

When it is desired to combine Pure Oxygen with the Nitrous Oxide, open valve, which admits Oxygen to the Mixing Chamber, and both flow together to the Inhaler.

This valve with its indicator plate is designed especially to enable the operator to follow out Dr. Hewitt's method, and to this end the valve aperture is enlarged regularly as the handle is turned from 1 to 10; beyond this the valve operates as an ordinary valve and may be opened to the full size of the tubing. It must be understood, however, that in using the indicator plate exact and predetermined percentages of the two gases are neither practical nor desirable.

There is a convenient handle by which the apparatus, which balances nicely, may be carried.

For compactness in transportation, the rod which supports the Inhaler may be run down to the level of the Mixing Chamber.

The Cylinder for Oxygen is always red.

The Cylinder for Nitrous Oxide is black, and there need be no mistake in placing them in the apparatus.

The cock O should be opened wide and the oxygen valve indicator P placed at, say 2, before the inhaler is applied to the patient's face. After the patient breathes air freely through the inhaler, shut off the air and then turn on the gas by pressing the spring valve K on the inhaler; at the same moment the assistant should open cock F to permit nitrous oxide to flow from the cylinder B to bag D. The indicator may then be advanced to 3, 4, 5, etc.

Pure Oxygen may be administered in a moment by simply closing cock O and throwing cock P full open.

In regulating the amount of oxygen admitted, the effects must be anticipated and the amount increased or diminished before the actual effect of such action is evidenced in the condition of the patient. The physical state of the patient should also be borne in mind, oxygen being sparingly used with those subjects who resist the anæsthetic, and rather freely with those who do not—such as children and delicate persons, also in subjects with pulmonary or bronchial difficulties. During long administrations it may be advisable to admit a breath of air occasionally. If there is troublesome stertor more oxygen should be given and the lower jaw be brought forward. A mouth-prop may be advisable in general surgical operations.

There are no special dangers connected with the administration of nitrous oxide and oxygen. So far as this method has been employed it seems to be remarkably free from danger.

Recovery from the narcosis induced by this method takes somewhat longer than from nitrous oxide alone, but is satisfactory, and there are usually no after-effects of importance.

CHAPTER IX.

ETHER.

Ether, ethyl oxide, ethylic ether, vinous ether, sulphuric ether has a chemical formula of $C_4H_{10}O$. It is said to have been discovered by Valerius Cordus about 1540, and was called by him "Oleum Vitrioli Dulce."

Ether fortior—stronger ether—is composed of about 94 per cent. ethyl oxide, and about 6 per cent. of alcohol containing a little water. Its specific gravity should be not higher than 0.725 at 60° F. All formulas for the preparation of ether agree in obtaining it from the action of sulphuric acid on alcohol. The term ether is used in relation to the grade recognized by the U. S. Pharmacopœia (sp. gr., 0.725 to 0.728), which corresponds to the pure ether (Æther purificatus) of the British Pharmacopœia, which has a sp. gr. of 0.720.

Ether is a thin liquid, very diffusive, transparent, highly volatile, with a characteristic, refreshing, pungent odor and sweetish, burning taste, a slightly bitter after-taste, and a neutral reaction. It is soluble in all proportions in alcohol, chloroform, benzol, benzin, fixed and volatile oils, and in eight times its volume of water at 60° F. Its boiling point is about 98.6° F. Ether is highly inflammable, and a mixture of ether vapor and air is violently explosive when ignited. These properties of ether should be remembered when administering it in the vicinity of artificial light, or in pouring it from one receptacle to another Serious burns have resulted from attempting to use the actual cautery about the mouth under complete anæsthesia with ether.

Light blue litmus paper moistened with water should not be changed when immersed in ether for ten minutes. If 10 c. c. of ether be poured in portions on blotting paper and evaporated spontaneously, no foreign odor should be perceptible after the last trace of ether has evaporated. When 20 c. c. of ether are shaken up in a graduated tube with 20 c. c. of water just previously saturated with ether, the etherial layer upon separation should not measure less than 19.8 c. c. (absence of undue amount of alcohol and water). If 10 c. c. of ether be shaken occasionally within one hour with 1 c. c. of potassium hydrate test solution,

no color should be developed (absence of aldehyde, etc.). If ether be agitated with carbon disulphide it becomes milky and turbid if water is present.—Boettger. One per cent. or more of alcohol may be detected by agitating ether with a fragment of aniline-violet, no color being produced if free from alcohol.—Stefanelli. Lieben's test for alcohol, founded on formation of iodoform from alcohol and not from ether, is the most delicate test for alcohol. The ether may be shaken with water, which removes the alcohol; the aqueous extract is then warmed, a few crystals of iodine are added, and as much caustic potash as is necessary to render the solution colorless; after standing a few hours a precipitate of iodoform will form. One part of alcohol in 2,000 may be detected by this method. Tests are given for methylated ether, acetic acid, sulphuric acid, and hydrogen peroxide, but it is not necessary to consider them here.

Physiological effects and action.—As an anæsthetic ether is much stronger than nitrous oxide, and not as powerful as chloroform. The toxicity of ether is comparatively slight. Prominent characteristics of ether are its stimulant nature to the circulation, respiration, nervous system, and glandular system, and its irritant quality to the respiratory mucous membrane. The toxicity of ether being slight, it is necessary to administer it in a more or less concentrated form in order to produce complete anæsthesia. It is freely eliminated, mostly by the lungs, and its effects are graduated by the degree of concentration of the vapor inhaled; that is, by the amount of air admitted during the administration. When little or no air is admitted during the induction of the anæsthetic state it is possible to anæsthetize with practically no manifestations of excitement, and the stages of anæsthesia, more clearly defined under more open methods of administration, are not therefore so manifest.

First stage.—Owing to the pungent nature and irritant character of ether, the first inhalations will cause a free secretion of mucus in the fauces, and a choking and suffocating sensation will occur if the vapor is too concentrated. The patient will push away the inhaler or try to move his head away from it. Repeated acts of swallowing may take place. A sense of fullness and pressure in the head, noises in the ears, warmth, tingling, or a pleasant numbness of the body may be felt. The pulse is quickened.

the respiration is accelerated, somewhat jerky, and deeper than normal. The pupils are somewhat dilated, and quite mobile.

SECOND STAGE.—As the administration proceeds consciousness is lost slowly or abruptly. While there may be response to questions or to stimulation, the answers will be irresponsible. Memory is lost, and actions are not rational. Hallucinations may be present. Laughing, singing, struggling may occur, especially in robust subjects who require considerable ether, or if the administration is not pushed rapidly enough. A degree of muscular strength may be exerted under these conditions which is quite surprising, and is frequently exaggerated if attempts to restrain the patient are made. There is usually more or less tonic muscular contraction, which later may become clonic, or, exceptionally, there may be fine muscular tremors. The face is flushed, perspiration breaks out freely on the forehead, face and body. The conjunctivæ become injected. Slight cyanosis may appear. Mucus and saliva are freely secreted, especially in young and robust subjects. The pulse is bounding and more rapid than normal. The breathing is more or less irregular from muscular spasms. There may be temporary suspension of respiration in muscular subjects. There may be disconnected attempts at articulation, muttering, or only respiratory noises, or groans, clenching of the teeth, and attempts at swallowing may result from spasm of the masseter or laryngeal muscles, especially if the vapor be too concentrated.

As the anæsthetic state becomes deeper the muscles become relaxed. The respiratory muscles and the muscles of the upper air passages are insensitive to reflex stimulation from the irritation of the vapor, and the patient passes into the so-called third stage of anæsthesia.

THIRD STAGE.—At this time the respiration becomes forcible, regular, and there is more or less stertor. There is more or less rattling from pharyngeal and laryngeal mucus. The corneæ are not sensitive. The extremities are relaxed, and complete anæsthesia is reached. There may be some spasm of the masseter muscles. The respiration is quicker than normal. Stertor may have a nasal character if the tongue is against the pharyngeal vault, as is common. The pulse is usually slower than in the earlier stages. It is full, bounding and regular, and may be

from 90 to 120 per minute in ordinary cases. Arterial pressure is normal or slightly below normal. The face is flushed, and the vascularity of the tissues of the upper part of the body is increased. Marked perspiration is frequent, and a rash may appear on the surface of the body. The pupils are usually moderately dilated. Under deep anæsthesia they may be markedly dilated, and in rare instances may be contracted.

The eyeballs are usually fixed in the horizontal plane. They show loss of associated movement, or co-ordinate action may be preserved. In lengthy administration there is more or less depression of the vital forces, and the body temperature is somewhat lowered.

Toxic effects.—When an overdose of ether is administered respiration shows signs of failure. The conjunctivæ become insensitive. The pupils are dilated. The eyelids become separated The skin is ashy pale. The pulse is weak and slower, but the change is not nearly so apparent as with respiration, which in some cases loses its stertor and becomes more and more feeble and finally ceases entirely. There may be prolonged, wheezy expiration with short, shallow inspiration, or the breathing may be very irregular, jerky and gasping. It is almost universally the case that when respiratory failure occurs the circulation is still of sufficient integrity to insure the success of properly performed efforts at resuscitation. The experiments of Lindermann, of Moscow, on animals, show that when death occurs from too prolonged or concentrated etherization there is always congestion and œdema of the lungs present.

Temporary arrest of respiration from reflex stimulation of the peripheral ends of the vagi and pneumogastric nerves may mark the initial stage of etherization. Observers generally note a stimulation of the circulation. Kemp's experiments on animals showed a raise in general arterial pressure. MacWilliam claims there is a general but slight fall in arterial pressure, and that cardiac dilatation is slight or absent except when ether is suddenly pushed in administration. According to Harley, the action of ether in interfering with the absorption of oxygen and the elimination of carbonic acid is not nearly so great as that of chloroform. Van Lerber claimed that ether has little or no effect on the hæmoglobin, and that spectroscopic examination does not

show increase in urobilin from corpuscular disintegration. Da Costa, however, claimed that ether causes a marked diminution of the hæmoglobin.

According to Kemp, ether produces a special contraction of the arterioles of the kidneys, and has a damaging effect on the secreting cells of the organ, with diminution of kidney volume, more or less suppression of secretion, and albuminuria not due to diminished tension. Other observers claim that these effects upon the kidney are not constant, and only appear under too rapid administration.

A number of years ago Lawson Tait observed, while operating on a case of vesico-vaginal fistula, that when the ether was pushed the trickling of urine from the ureter ceased, indicating suppression of the kidney function, and therefore the dangerous nature of ether in kidney disease. Thomas and Kemp have since demonstrated the same fact by experiments on animals, and conclude that ether is dangerous in renal diseases, and particularly so if there is a tendency to pulmonary œdema. In fifty cases examined by Blake ether produced albuminuria or increased it when already present.

Hooper, of Boston, has shown that under light anæsthesia, stimulation of the recurrent laryngeal nerve produces adduction of the vocal cords, while under deep anæsthesia it produces abduction.

THE AFTER EFFECTS of etherization are more marked and unpleasant than those of other general anæsthetics. Recovery from the effects may be rapid or slow. When the patient is anæsthetized in the lateral, prone position, and is not saturated with large quantities of ether, recovery is usually rapid and satisfactory. A too free use of ether may be followed by prolonged stupor, slight cyanosis, and weak pulse. Slight cyanosis is usually corrected when the throat is cleared of mucus by coughing or vomiting. Ether leaves a disagreeable taste in the mouth, and its odor is present in the breath for some time. Moderate, sudden, expulsive vomiting usually occurs. It ceases quickly, may be repeated once or twice, and usually occurs before the patient has fully regained consciousness, leaving the patient quietly asleep. There may be repeated attacks of vomiting after prolonged anæsthesia in certain subjects. Hæmatemesis may rarely

occur, but is unusually slight and unimportant. Hæmoptysis is quite rare, and may or may not be significant. Bronchitis, usually mild in degree, is not uncommon after etherization, particularly in predisposed subjects or after prolonged administration.

Pneumonia is more frequent after etherization than was formerly thought. According to Anders it occurs once in 300 cases. Ether pneumonia is usually lobular in character. Lobar pneumonia sometimes occurs after etherization, but in this event it is not clear that there is direct relation between the etherization and the pneumonia, unless it be the effect of etherization in producing better conditions in the respiratory tract for the development of organisms which are already present. Prescott believes that ether cannot cause true lobar pneumonia. He cites two cases in 40,000 ether inhalations. In the lobular pneumonias, which are the most frequent, it is likely that the extra secretion of mucus, the interference with the action of the respiratory muscles and the diaphragm, especially in abdominal operations, in connection with which pneumonia is most frequent, the pain and coughing all favor the occurrence of aspiration pneumonia, as suggested by Czerny. It has been thought that the chilling of the respiratory tract produced by the rapid evaporation of the ether was the cause of the pneumonia; also that chilling of the surface of the patient's body during operation was responsible, or that the pneumonia might be due to the direct irritant action of impurities in the ether, or to the ether itself, or to infection from the inhaler. We do not, however, comprehend the relation of lowered vitality of the tissues from prolonged etherization (relative) to the presence of organisms in the respiratory tract.

The question of ether pneumonia was introduced by Mr. Lucas, of Guy's Hospital, London. Prescott, of Boston, found three cases of acute lobar pneumonia in 46,000 etherizations. Silk, of London, 13 of pneumonia in 5,000 cases. Gurlt, 30 cases in 52,177. Of 15 cases of ether pneumonia in Johns Hopkins Hospital, 15 were lobular in character, and 79 per cent. followed abdominal operations.

Albuminuria appears in some instances after etherization. Observers vary greatly in their estimate of the proportion of cases,—all the way from a quarter of one per cent. to two or three

per cent.—of a considerable number of cases in which previous albuminuria was absent. Kemp argues in favor of rather frequent appearance of renal complications after ether, while Buxton and Levy are not satisfied that, properly administered, ether exerts injurious effects upon the kidney. The preponderance of evidence is in favor of etherization as an ætiological factor in renal disease in a certain unknown small proportion of cases.

Hysterical, neurotic or alcoholic subjects may exhibit mental excitement, or even mania or dementia. Chorea has also been noted. Cerebral hæmorrhage has been reported as an effect of etherization, and Murchison reported jaundice as following etherization.

The dangers connected with the administration of ether to healthy subjects are almost nil. It is claimed that only one in fifteen thousand persons who inhale ether die, and that ether is only one-fifth as dangerous as chloroform. The combined statistics of Gurlt, of Berlin, and Juillard, of Geneva, give 341,058 cases of ether inhalation, with 23 deaths. In the report of Committee of the British Medical Association of 1900, there is given 4,595 cases of ether inhalation, with 14 cases of danger, which include 6 fatal cases, none of which are regarded as being solely due to the anæsthetic. Partial occlusion of the upper air tract may result from too much ether, but also occurs with moderate anæsthesia. Spasmodic cessation of respiration from tonic spasm of the chest muscles may occur with incomplete as well as with deep anæsthesia. The respiration may suddenly cease before or during a properly induced anæsthesia. The chest is rigidly fixed and resists any efforts to induce expansion or contraction. In some cases respiration is resumed spontaneously. In others death may follow if artificial means are not successful. Laryngeal spasm with high-pitched, sibilant inspiration, and more or less cyanosis may occur, but rarely arrests respiration, and, as a rule, does not last long. Temporary embarrassment of respiration may occur during the period of recovery just preceding vomiting. It is usually not attended with depression of the circulation.

Primary cardiac failure from the effects of ether *per se* is an extremely rare event in moderately healthy subjects. In some cases under operations which entail a severe degree of surgical

shock, death may occur under ether from primary cardiac syncope. In persons with weak, dilated hearts, or advanced myocardial degeneration, death may be from cardiac failure even though signs of respiratory failure be present, the asphyxial state, together with the strain of vomiting or struggling being a sufficient additional tax on an incompetent heart to insure death from cardiac syncope. In eleven cases of death under anæsthesia in which ether was employed, either alone or in conjunction with other anæsthetics, included in the report of the Anæsthetics Committee of the British Medical Association, rendered in 1900, not one was attributed entirely to the ether. Brooks, of New York, recently reported an instance of death from etherization in which respiration ceased suddenly two or three minutes before the heart stopped. Autopsy failed to disclose evident cause of death. Brooks attributes death to the action of the drug on the ganglion cells of the respiratory center.

Foreign bodies, such as blood, pus, vomited matter, etc., may enter the larynx or trachea and constitute a source of danger.

The administration. Ether may constitute the sole agent used for the administration—the usual method adopted,—or it may be given as a constituent of a mixture containing other anæsthetics—the so-called anæsthetic mixtures, such as the A. C. E. mixture; or it may be administered in sequence with other agents—the so-called method of anæsthetic sequences.

The present consideration has reference solely to the use of ether as the only agent employed for the administration.

As a rule the administration of ether is carried to the point of complete anæsthesia. In relatively few instances this may not be necessary. Twelles claims that two-thirds of all operations may be performed under a method that has been used in Vienna, in which the patient is kept on the borderland between awakening and the stage of excitement (the "ether rausch" or "ether drunk") by using from 10 to 30 c. c. of a mixture of ether and balsamic oil inhaled through an ether mask. Analgesia is said to follow from ten to fifteen deep inhalations, and the operation can be commenced within a minute of the beginning of the administration. The practicability of this method, however, remains to be demonstrated. It is not adapted to excitable and highly nervous persons.

When possible it is best to begin the administration with the patient upon the operating table, or at least not to lift or haul the subject about after anæsthesia is induced. The posture of the patient during the administration will, of course, vary with the demands of the operation, but the prone position with the patient upon the side or back and the head turned slightly to one side is, generally speaking, to be preferred. The irritating effects of ether upon the membrane of the fauces, and the choking sensation incident to the beginning of its inhalation should be explained to the patient. He should also be instructed to breathe deeply and regularly through the mouth.

The manner of administration will vary with the method adopted and the kind of inhaler employed. Inhalers are of varied designs, many of which exemplify much more ingenuity than practicability. The simplest inhaler which will answer for the method of anæsthesia employed is always the best, and the inexperienced administrator should employ the simplest apparatus, such as the open inhalers.

Ether is generally administered according to the so-called open method, the partially closed or semi-open method, or the close method. It may also be administered in conjunction with oxygen and may be administered per rectum.

By the OPEN SYSTEM of administration an abundance of air is allowed during the entire period of administration. The ether is poured in small quantities on a folded napkin or handkerchief, or on a mask inhaler of gauze or lint which is held quite close to the mouth or nose. It is difficult to induce complete anæsthesia by this method, and its use is adapted only to very young children, weak or exhausted subjects, or to persons who have been for some time under the influence of ether and who therefore do not require much to continue the anæsthetic state.

By the PARTIALLY CLOSED OR SEMI-OPEN method of administration the amount of air admitted is limited to a greater or less extent, and the expired air and vapor escapes, no re-breathing taking place. There are many varieties of inhalers applied to this method of administration. The earliest and simplest was made by folding a towel into a cone shape and placing a sponge or piece of gauze in the apex. A simple and efficient inhaler of this kind may be extemporized by doubling a towel over two

or three layers of newspaper, folding over and pinning down the edges and one end, pressing the open end into an oval shape, and loosely packing the upper part of the interior with gauze or a sponge. Inhalers for this method of administration are made of metal, felt, mackintosh, or leather, with open or perforated apices. If the apex is not closed the ether may be poured on in small quantities as may be necessary without removing the inhaler from the face, sufficient air being obtained through the apparatus. Representative types of this class of inhalers are the Allis (Figs. 24, 25) and the Blake inhalers, while the Goldan inhaler represents a simple form adapted for either open or close administration.

It is well to rub a little vaseline on the lips and adjacent portions of the face of the patient in order to avoid the irritation of the ether. Two or three drachms of ether are poured in the inhaler which is held a short distance from the face until the patient gets accustomed to the sensation of inhaling the vapor.

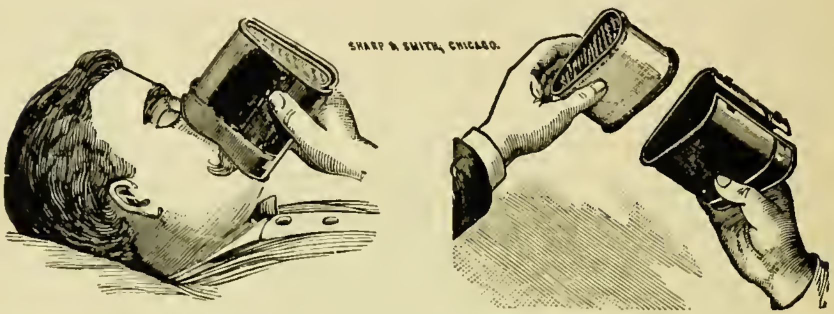


Fig. 24.—Allis' Inhaler with Detachable Metal Cover.

Fig. 24. A metallic frame-work large enough to cover the lower portion of the face and so fenestrated as to admit the introduction of a large number of cloth partitions. These partitions are formed from a gauze bandage by weaving the cloth back and forth through the fenestræ in the sides of the frame. Although the instrument is only about 4 inches in length and from 2 to 3 in width, it requires about three yards of gauze bandage to form the partitions. The whole is surrounded by a nickel-plated cover held in place by suitable spring clips. This arrangement provides an instrument durable, portable, inexpensive, and easily sterilized. One end of the external covering is so arranged as to fit closely the contour of the face. The apparatus allows the free admission of air from above, and as the evaporating surface is large, rapid vaporization and etherization follows. The quntity of ether may be replenished as fast as desired by pouring it upon the outer surface of the exposed gauze edge.

Too sudden inhalation of strong vapor will cause coughing, holding of the breath, choking, or a distressful sensation of suffocation. As the patient becomes accustomed to the vapor and is beginning to lose consciousness the amount of air is restricted and the strength of the ether vapor inhaled is gradually increased. Careful attention should be given at this time to the respiration and to the larynx. The rhythm of the respiration is usually somewhat irregular because of swallowing, and temporary spasmodic closure of the larynx is apt to occur if vapor be too strong. The larynx soon loses its sensibility and the breathing becomes regular. If excitement becomes marked, as is likely at this time, it may be controlled by pushing the administration—a much safer procedure with ether than with chlo-

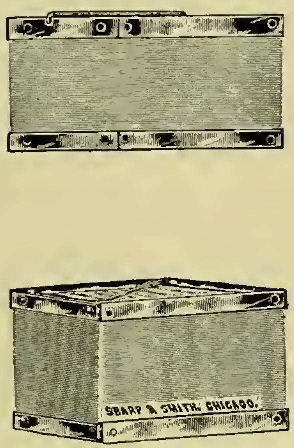


Fig. 25.—Fowler's Modification of Allis' Inhaler.

roform at a corresponding period of administration with the latter agent. In robust, vigorous subjects and in alcoholic persons a larger quantity of ether will be necessary to prevent excitement and to maintain deep anæsthesia than will be required in debilitated subjects. The longer the administration lasts the smaller will be, as a rule, the quantity of ether necessary to prolong the anæsthesia. If the patient is not allowed to partially recover from the effects of the ether during the administration vomiting will not be liable to occur. Much more ether is required by the semi-open system than by the close method with

bag inhalers, and excitement and struggling are more liable to occur. It is thought by some that there is also greater liability to subsequent respiratory affections. Nevertheless, for many subjects, and for a great many operations the semi-open system of

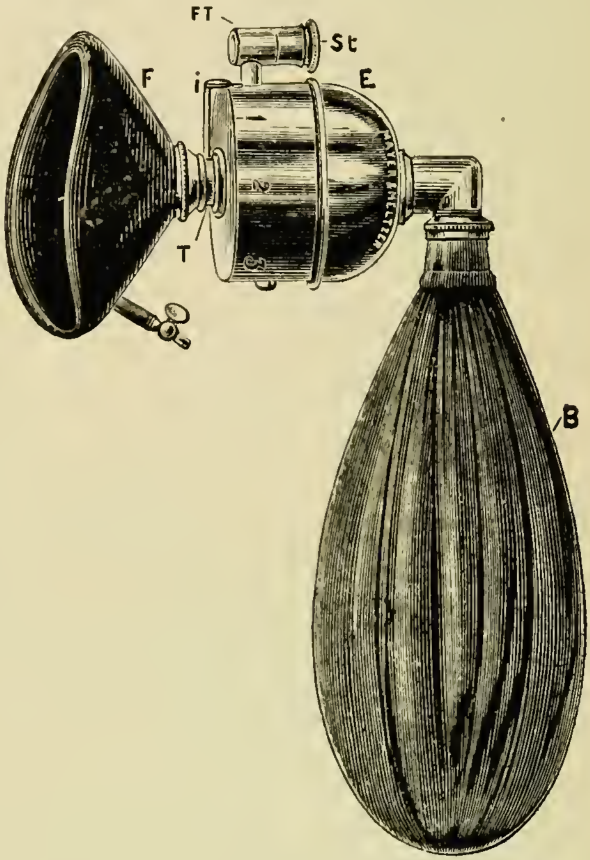


Fig. 26.—Clover's Portable Regulating Ether Inhaler (original pattern).—After Hewitt.

Fig. 26. F is the face-piece; E is reservoir through which air current passes; B is a rubber bag. The patient breathes back and forth into the bag. There are no valves and no arrangement for admitting fresh air. The face-piece fits tightly to the tube T which connects with a shaft passing through the reservoir. The mounting of bag B fits into the other end of this shaft. The current of air is regulated in passing over the ether by revolving the reservoir on the tube T. The reservoir is charged at the funnel-shaped tube FT.

administration is preferable. The moderately experienced administrator will certainly encounter less difficulty in anæsthetizing by this method, and it is therefore the most popular and widely employed system.

By the CLOSE METHOD of administration the amount of air admitted is restricted and under control, and the expired air is rebreathed to a greater or less extent. The names of Smith, of New York; Porta, of Pavia; and Morgan, of Dublin, are connected with the introduction of inhalers adapted to this

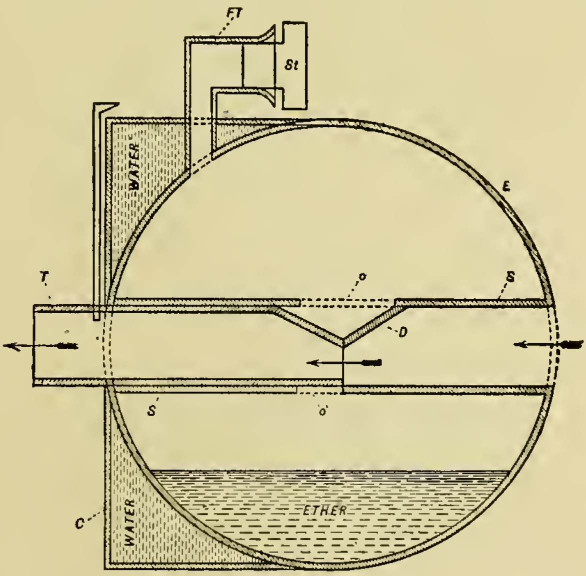


Fig. 27.—Sectional view of Clover's Inhaler. Indicator at "O."—After Hewitt.

Figs. 27, 28. Shows the reservoir F and tube T in section. E is a sphere tunnelled by shaft S into which T fits. E holds the ether which is entered at tube FT closed by stopper St. One-half of the sphere is covered by a cap C. The space between C and E is filled nearly with water which prevents the inhaler from becoming too cold. In the shaft there are four large openings, two (O) on upper wall, and two (O') on lower. These allow communication between interior of shaft and ether reservoir. The shaft contains a sloping diaphragm D closing one-half of the shaft. The tube T passes into the shaft S and has a beveled end which fits close against the diaphragm of the shaft. It has an indicator (*i*) pointing to figures on the reservoir. With the indicator at "O" the air current on inspiration will take the course shown in Fig. 27. With the indicator at "F" the air current on inspiration will take the course shown in Fig. 28.

method of administration. The Clover inhaler (Figs. 26, 29), introduced in 1876, may be regarded as the type of the bag inhalers used in this method. The Packard inhaler, the Bennett inhaler (Figs. 30-32), and other modifications of similar nature embody the principles of the original Clover inhaler. Young has suggested an improvement in the use of bag inhalers which consists in using a linen bag instead of the rubber one. A clean bag can be used for each patient, as the rubber bag gets foul and cannot well be cleaned. Other advantages claimed are: Less

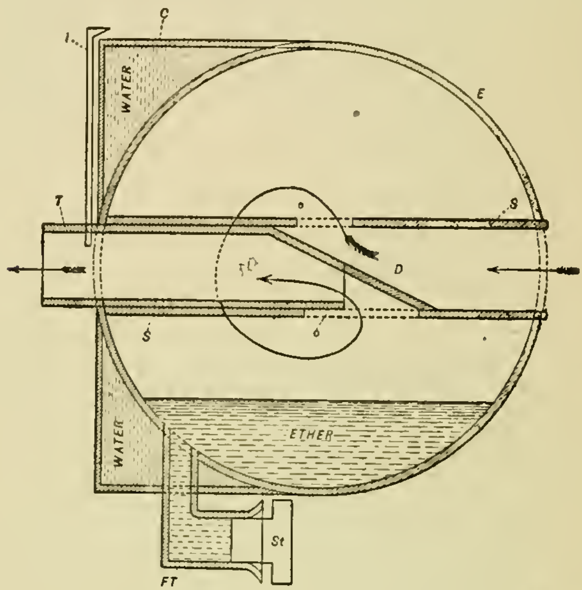


Fig. 28.—Sectional view of Clover's Inhaler. Indicator at "F."—After Hewitt.

initial disturbance, no asphyxia or cyanosis, and if a change to chloroform is desired it can be dropped on the bag without changing the face-piece. Slight disadvantages are: Longer inhalation period required for anæsthetization (average, ten minutes), and increased quantity of ether required (about one ounce for every ten minutes). In the administration by this method attention should be given to the following points: See that the face-piece fits properly; in beginning the administration direct the patient to breathe through the mouth regularly and deeply; leave the indicator at "air" and allow to-and-fro breathing from the bag

for a few seconds in order to partly fill the bag with air, and to see that the bag expands and contracts properly with respiration, keeping the face-piece closely applied during expiration; gradually turn the indicator towards "ether" every two or three respirations. As anæsthesia becomes effected ether may be admitted rather more freely; coughing, swallowing, and holding the breath indicate less ether and more air; excitement indicates more ether and less air. If there be stertor the face-piece should be raised and a breath or two of air allowed. As the administration is prolonged more air may be admitted without affecting the anæsthesia; slight cyanosis is present as a rule during the beginning of the administration. In the later stage cyanosis indicates more air; marked stertor, deep cyanosis, difficult breathing, and forced expiration call for more air at once. The signs of anæsthesia are regular, snoring breathing, lost corneal

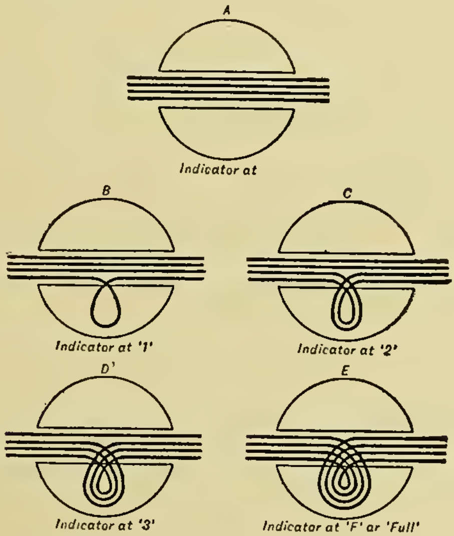


Fig. 29.—Diagram of Air Currents in Clover's Inhaler.—After Hewitt.

Fig. 29. Diagram of air current passing over ether in Clover's Portable Inhaler when indicator points to "O", "1", "2", "3", and "F" Four lines represents the full current.

In preparing to use Clover's inhaler secure a properly fitting face-piece, turn the indicator to "1" or "2"; pour in one and one-half ounces of ether; replace the plug; turn back the indicator to "O"; blow once through the apparatus to remove odor of ether, and attach the bag.

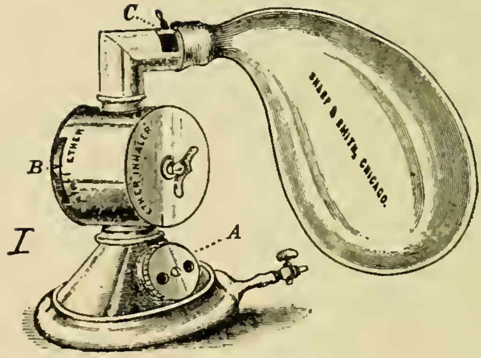


Fig. 30.—Bennett's Inhaler for Ether.

Figs. 30, 31, 32. I. Ether Inhaler.—Take the ether chamber apart by removing the thumb-screw. Pack the wire cage (*in situ*) firmly with dry gauze. It will hold a piece one yard wide and ten or twelve inches long. Do not allow the ends of the gauze to interfere with the mechanism of the inhaler. Turn the index to the upward limit (full ether) and pour from one-half to one ounce of ether upon the gauze—one-half through the face-piece, the other half through the chimney at the top of the ether chamber. Now turn the index to the downward limit (full air) and attach the bag. The rubber cushion of the face-piece should be moderately inflated. The air tap at *a* and at *c* should be closed. Apply the face-piece during several expirations, so as to distend the bag moderately; then keep the inhaler applied and turn the index at once to the line between *air* and *ether*. Now turn the index toward *ether*, about one-sixteenth inch every two or three inspirations, or as slowly as necessary to avoid the effects of too strong ether fumes. In about one minute the index will have been moved forward one-fourth to one-third the distance between the *line* above referred to and the *upward limit*. Occasional inspirations of air should now be given by removing the inhaler from the face, and the index should be moved more gradually forward until complete anæsthesia is present. This is accomplished in from two to five minutes in average patients. When the index has reached a little more than one-half the distance from the *line* to the *upward limit* full ether is on and the index should be at once moved to the *upward limit*. The administration consists chiefly in the regulation of two facters: 1. The air supply, and, 2, The ether supply.

1. The Air Supply.—During the induction of anæsthesia the air supply should be limited as above; enough should be given, however, to prevent more than slight cyanosis. Patients differ greatly in the amount of air they require with ether, and the air supply must be regulated in accordance with the following facts: The tap *c* being closed, if *a* is opened slightly the patient will rereive little air and much ether; if fully opened he will receive much air and little ether. The tap *a* being closed, if *c* is opened slightly the patient will receive little air and much ether; if fully opened, he will receive much air and much ether.

2. The Ether Supply.—At the beginning, the ether chamber should be charged, as above, with from one-half to one ounce of ether, according

to the patient, and this will usually be sufficient to induce complete anæsthesia. It is best to continue the administration with the index turned to the *upward limit,* and from one-half to one drachm of ether every two or three minutes will be found enough for the average patient. Ether may be added, (1) through the face-piece, (2) through the chimney, or (3) through the revolving disc on the side of the ether chamber: (1) is preferable in usual cases, (2 or 3) is of great advantage when it is inconvenient to remove the inhaler from the face.

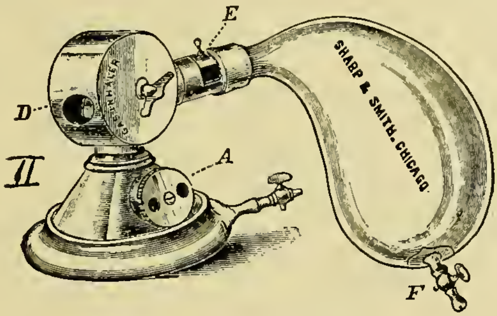


Fig. 31.—Bennett's Inhaler for Gas.

II. Gas Inhaler. The tap *c* being fully opened, the bag is filled with gas from the cylinder through the rubber tube supplied with the inhaler. The aperture *d* should be fully open. The rubber cushion of the face-piece should be moderately inflated. The face-piece should be applied so perfectly that the valves act well, the inspired air entering at *e* and the expirations escaping at *d.* Upon closing the tap *e,* gas will be drawn from the bag on inspiration, escaping at *d* on expiration. As soon as the inhalation begins, a flow of gas sufficient to keep the bag moderately full should be turned on from the cylinder. The inhalation is to be conducted on the principles of gas administration. Air may be admitted as necessary by opening the tap *e.*

reflex, and relaxed muscles. The regulation of the ether and air supply during the continuance of the anæsthesia will depend on the nature of the patient. Vigorous and alcoholic subjects require much more ether than weak or very young individuals. The amount of ether required is, as a rule, in inverse proportion to the length of the administration.

The conjoined use of OXYGEN AND ETHER has not had wide employment. It is claimed to possess marked advantages by some, and by others said not to have any special advantage except in certain cases. In employing this method the tube from an oxygen cylinder is connected with any inhaler adapted for the purpose—such as the Packard inhaler, and a greater or

less percentage of oxygen is admitted along with the ether. This method is adapted to persons with chest lesions and very weak hearts, emphysema, indurative pleurisy or mediastinitis, pulmonary sclerosis and advanced tuberculosis of the lungs. These conditions, especially when associated with secondary myocardial changes may render such a system of anæsthetization advisable, though even here some people prefer a chloroform mixture such as the A. C. E. mixture, providing the heart is not seriously compromised.

Dr. Dudley Buxton recommends the use of oxygen and ether

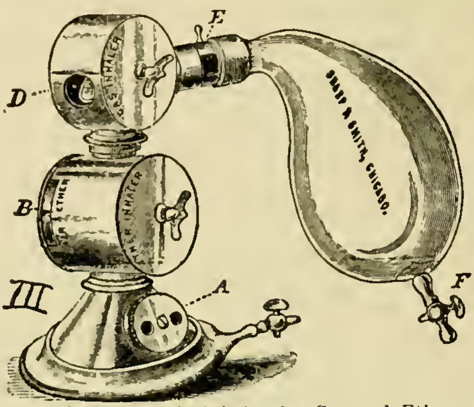


Fig. 32.—Bennett's Inhaler for Gas and Ether.

III. Gas and Ether.—The ether inhaler is charged with ether and arranged as described in I., the bag being omitted. The gas inhaler is arranged as described in II., the bag being completely filled with gas and disconnected from the tube at the stop-cock *f*, which is to be closed. The gas inhaler is now connected with the chimney of the ether inhaler. The face-piece being perfectly applied, the tap *e* is closed and gas is breathed through valves. When the gas bag has been two-thirds or three-fourths emptied, the aperture *d* is closed by turning the thumb-screw of the gas inhaler. Gas is now breathed back and forth. The patient is at this time unconscious, or nearly so, and ether is to be turned on as described in I., though somewhat faster. In about one minute signs of complete gas anæsthesia will appear if the face-piece has been well applied (cyanosis, jerky, snoring respiration, twitching movements in the extremities) and are to be met by opening the tap *e* for two or three respirations. The tap is again closed and the inhalation of gas, plus ether, is continued—an occasional breath or two of air being allowed. In this way the gas anæsthesia subsides, while the ether narcosis becomes complete. After about one and one-half minutes the gas may be discontinued, the gas inhaler and bag should be removed and the ether bag substituted. The administration now proceeds as described under I.

"In cases in which the induction presents unusual difficulties from dyspnœa, spasm, cough, holding of the breath, struggling with cyanosis, in alcoholics, and in persons of feeble vitality. The repeated filling of the bag with oxygen removes all difficulty, and rapidly induces a profound and quiet anæsthesia. The narcosis so obtained can be insured when using ether by itself, as the hyperoxidation of the tissues enables more ether to enter the circulation than could otherwise occur without danger to the nervous center hampered by deoxidized blood." This method is endorsed by Gardner, who says he finds muscular relaxation more complete under this combination than with ether alone.

Rectal etherization was introduced by Roux in 1847. It was employed with the object of obviating the usual method of administration in operations about the mouth and nose, or pharynx. The best method of introducing the ether is that of Mallière, who connected the ether bottle with a rubber tube which was introduced into the rectum, and the ether bottle surrounded with water at a temperature of 122° F., and the ether allowed to gradually enter the rectum. About 2 ounces of ether was usually needed. In a few minutes the patient can taste the ether, and drowsiness is felt. Excitement is rare. There may be prolonged stupor and asphyxial symptoms, with contracted pupils. Diarrhœa and melæna may follow. Weir, of New York, has reported an instance of melæna followed by death in a child after rectal etherization. W. T. Bull, of New York, reported seventeen cases of rectal etherization, with melæna in seven. Aside from these apparent objections, this method of etherization has advantages in certain cases, but under such liabilities it cannot be recommended except in rare instances.

The proper extent of anæsthesia to be maintained during the operation will depend on several circumstances. Too light anæsthesia during the early stages is apt to be accompanied by excitement, muscular movement or spasm, vomiting, etc. The third stage of anæsthesia should be maintained during the earlier part of operations. Later it may not be necessary to maintain so deep a state of narcosis. The amount of ether necessary to maintain deep anæsthesia will vary with the characteristics of the subject, and the nature of the operation. In some subjects the reflexes are difficult to abolish and much ether may be required. Again,

in some persons analgesia sufficient for minor operations may be secured, even though the reflexes are present. There is not the same danger of reflex failure of the circulation under light etherization that exists under the same state of anæsthesia from chloroform. The administrator, therefore, may keep the subject under as light anæsthesia as is compatible with no modification of the signs of the anæsthetic state by the operative procedures. In order to do this he must carefully observe the state of the respiration, the lid-reflex, the pupils, swallowing movements, and the degree of muscular relaxation. The respiration is the most reliable guide. The more ether given, the deeper, quicker, and more stertorous the breathing will be. Diminution in the amount of ether beyond that amount necessary for complete anæsthesia will be marked by inaudible breathing and absence of stertor. Expiratory puffing of the lips is also an indication of full anæsthesia. Slight obstructive breathing is often present under light anæsthesia and is remedied by pushing the lower jaw forward. It may or may not be necessary to maintain a stertorous form of breathing in certain instances. Prolonged, forcible expiration, tracheal, or laryngeal rales indicate less ether.

The lid-reflex is a good guide in many cases. The corneal reflex is often present when the conjunctival reflex is absent. The latter is temporarily abolished by repeated testing. Whether it is advisable to keep the lid-reflex abolished depends on the subject and on the operation. In some cases it is quite possible to have sufficient analgesia without abolishing the reflex. Generally it is best to abolish the reflex, especially in operations on the skin, abdomen, rectum, vagina, etc. In some operations, and in weak, debilitated subjects, it is often not necessary.

The pupils afford more or less reliable information as to the state of anæsthesia. In the third stage they lose their mobility and acquire a degree of contraction depending on the peculiarities of the subject. The average pupil of complete anæsthesia is about $3\frac{1}{2}$ to $4\frac{1}{2}$ mm. in diameter. Where the administrator has observed the size of pupil present 15 or 20 minutes after the beginning of the administration, and under full anæsthesia in a given subject, he is prepared to draw inferences from variations from this as a standard. If the amount of ether be too small to maintain full anæsthesia the pupil will contract and the patient will show other

signs of recovering, such as swallowing or other muscular movements. If too much ether is given, the pupil will dilate. In some cases the pupil will dilate under reflex stimulation from the operation if the anæsthesia is too light. This may happen in operations on sensitive tissues, or in neurotic individuals. It is distinguished from toxic dilatation from too much ether by the presence or absence of other signs, such as lid-reflex, or by the effect of less ether. If the pupil becomes small with less ether the dilatation was due to too deep anæsthesia; if it becomes dilated with less ether the dilatation was due to reflex stimulation. Thus the pupil may be about 3½ mm. under full anæsthesia, and may dilate to 5 mm. from reflex irritation during certain phases of the operation and slight anæsthesia; it may contract to 3½ mm. under more ether or absence of reflex irritation, and later dilate from the toxic effect of too much anæsthetic.

Swallowing movements may be an early indication of returning consciousness when the breathing has been regular, deep, and stertorous. They may precede vomiting, and the latter may be prevented by increasing the ether, if swallowing is observed or felt with the fingers on the larynx..

Muscular movements of the arms and legs are often an early evidence of too light anæsthesia, and like alterations of the pupils may occur from reflex irritation. Their indications are much the same, though more erratic and less reliable.

The management of accidental conditions incidental to the period of administration.—A certain class of subjects are more likely to exhibit accidental conditions of more or less danger during the administration than are others (page 41). Likewise certain operations are more frequently accompanied by manifestations of a dangerous nature than others (page 49). Nevertheless in all instances the administrator must be on the watch for, and prepared to meet any unusual condition that may arise.

At the beginning of administration irregular or inefficient breathing may result from too strong vapor, and a little air may be necessary. In some subjects fear, nervousness, or stubbornness may be the cause of inefficient breathing. Patience, firmness and encouragement on the part of the administrator will accomplish much. Interference with respiration may occur from the tongue becoming applied against the pharyngeal wall after the

patient is completely unconscious, and it may be necessary to open the mouth and pull the tongue forward with forceps. Unusual nervous or muscular excitement may be controlled by pushing the ether—a proceeding not dangerous at this stage in moderately healthy or vigorous persons. Muscular rigidity may persist even though unconsciousness is complete. It may disappear in some cases if more air be allowed. It may be necessary to give large amounts of ether with plenty of air in order to overcome rigidity. The breathing through the mouth should be unobstructed. In some cases it may be necessary to give a little chloroform in order to relieve muscular rigidity, and to resume the ether afterward. Muscular tremor, most common in muscular subjects under ether, especially in the limbs if exposed, may be relieved by changing the position of the limbs, or by increasing the amount of ether.

Coughing usually occurs early in the administration from too concentrated vapor, especially in subjects with irritable throats from the use of alcohol and tobacco. It does not occur during deep anæsthesia. It is preceded by attempts at swallowing. Occasional coughing may not be objectionable if there be blood or mucus in the respiratory passages. It is not always possible to prevent coughing, and in some operations when the act interferes with the operator it may be necessary to resort to chloroform.

Hiccough is rare, but is likely to occur during abdominal operations. The depth of anæsthesia has little influence on hiccough.

Sneezing may be troublesome, and if not relieved by pushing the ether the nasal region may be sprayed with a dilute solution of cocaine.

Vomiting is frequently troublesome and occurs under light anæsthesia, usually during the induction period or during the recovery from full anæsthesia. It is objectionable for evident reasons and may be dangerous. Vomiting is most likely to occur in alcoholic, robust young men and in weak women with irritable stomachs and sluggish livers. The secretion, during anæsthesia, of a large amount of saliva and mucus produces vomiting. The quicker and more completely the subject is brought under the anæsthetic the less liability there will be to vomiting. Once fully anæsthetized the subject can usually be kept from vomiting by increasing the amount of ether, should swallowing, high-pitched

respiration, or a dilated pupil with good conjunctival reflex be observed. If vomiting cannot be prevented, the patient's head should be turned well to one side and the opposite shoulder propped up. If the teeth are clenched the mouth should be forced open and the lower jaw pushed forward.

The respiratory difficulties arising during etherization are due, in the early stages of administration, to some interference with the entry and exit of air. While during deep anæsthesia respiratory troubles may arise from interruption of the function of the respiratory center from an overdose of ether or from other causes. It should be borne in mind that during the induction of anæsthesia muscular movements, especially of the diaphragm, may simulate those of respiration in cases where there is some obstruction to breathing. The air current should be heard or felt, or its effects on the bag of the inhaler observed in order to be sure that the patient is breathing.

Obstructed breathing from spasm of the muscles of the upper part of the respiratory tract may be remedied by pushing the lower jaw forward, pulling the chin forward from the sternum and upward, and by extending the head over the end of the operating table. It may be necessary to introduce a mouth-gag, open the mouth and pull the tongue forward from the pharynx. If breathing is not resumed, strong traction should be made on the tongue, and the chest should be compressed. Crile calls attention to the fact that dangerous inhibitory phenomena may attend the too sudden and forcible traction of the tongue during anæsthesia, cyanosis, collapse, and failure of the heart and respiration becoming suddenly pronounced. The effect on the heart is produced by mechanical irritation of the vagi and is prevented or relieved by atropine. The effect on the respiration is through mechanical stimulation of the superior laryngeal nerve and is not relieved by atropine. Where the trouble is due to mucus it will generally be relieved by coughing and swallowing, which will come on if the administration be suspended. In very rare instances in fat subjects of a powerful build, spasm may be so intense and swelling so great that the air tract is closed entirely, and laryngotomy may be necessary. This, with Sylvester's method of artificial respiration, will generally bring relief. Inflation of the lung through a tube introduced into the larynx may be necessary, using the

mouth, a bellows, or the Fell-O'Dwyer apparatus. As the immediate cause of death is from overdistention of the right heart, venesection may be of service.

Obstructed breathing may arise from various foreign substances in the air passages. In operations about the mouth and throat blood may enter the larynx and trachea and cause sudden or gradual obstruction of the breathing. If moist expiratory rales are heard the administration should be stopped and careful sponging with a coarse-meshed sponge practiced. This may be followed by forcible compression of the chest and abdomen, inversion of the patient, artificial respiration, keeping the mouth open and the tongue pulled forward. The rectum may be stretched, and ether poured on the abdomen. Laryngotomy may be necessary and suction through a tube introduced into the trachea may be tried. Lung inflation may be useful.

Vomited material may enter the trachea. In rare instances it may be impossible to prevent this occurrence. If vomiting is probable the head should be kept turned to one side, the opposite shoulder elevated, and the mouth kept open by a gag. Should trouble arise from this source the measures enumerated above should be applied.

Mucus and saliva or pus may be troublesome, though usually it may be obviated by close atttention to the anæsthetic and its regulation. The mucus should be frequently sponged from the fauces, and if trouble arises the above line of treatment is indicated.

Certain postures in which it may be necessary to place the patient for certain operations may aid in obstructing breathing. The remedy is obvious. Certain pathologic states of the organs within the chest or abdomen may tend to produce interference with respiration. In these cases moderate anæsthesia only is permissible.

General spasm of the respiratory muscles is an infrequent form of respiratory disturbance in ether anæsthesia. It is neither so frequent or dangerous as in chloroform anæsthesia. It may arise during the stage of excitement, or from the reflex impression from surgical procedures—such as skin incisions, or as a sequence to obstruction of the air tract. When the rigidity of the chest from such spasm does not subside spontaneously, the

mouth should be opened, tongue traction made and artificial respiration employed. If these fail, laryngotomy should be performed and lung inflation practiced.

Respiratory failure from an overdose of the anæsthetic is rare in etherization. Sudden arrest is not as frequent as with chloroform. Shallow, imperceptible respiration, and stridulous expiration, especially if associated with dusky pallor, lost conjunctival reflex, and weak or irrregular pulse, are the danger signs. In etherization, if such signs occur, the pulse usually remains of sufficient integrity to insure a response to artificial respiration if promptly applied. Fuller consideration of this matter will be found under chloroform (p. 144).

Respiratory failure from cerebral anæmia, or from reflex causes arising during operation is not so frequent under ether as with chloroform anæsthesia. Inversion of the body, artificial respiration and hypodermic injection of strychnia (about one-twenty-fifth of a grain) are of service.

Failure of the circulation is uncommon under ether, but may occur from the same causes as in chloroform anæsthesia (p. 147). Various impaired conditions of the general health, pathological changes in the blood or in various organs may predispose to failure of the circulation under etherization, as may also psychological conditions, mental disturbances, or the posture of the patient during anæsthesia. Food in the stomach, spasmodic arrest of breathing, vomiting, the operation and the effect of the anæsthetic on the cardio-vascular system may all induce failure of the circulation in certain cases. The management of this condition will be considered under chloroform (p. 147), as it is most frequent under that anæsthetic. Ante-mortem heart thrombus has been reported as a cause of death during etherization. Such a cause could not, of course, be recognized, nor its effects obviated.

The clinical conclusions arrived at in regard to ether by the last committee on anæsthetics of the British Medical Association are to the effect that complications are more frequent in males than in females, but are slightly more dangerous in females than in males; that ether alone, or preceded by gas or A. C. E. mixture, is singularly free from danger in healthy patients; that the minor difficulties of administration due to laryngeal irritation and secretion of mucus are more frequent under ether than under other

anæsthetics; that struggling is most frequent under ether alone, but rarely leads to danger; that vomiting during recovery is most common with ether, but is usually transient; that bronchitis is more common after ether than after chloroform.

CHAPTER X.

CHLOROFORM.

Chloroform, also called trichlor-methane, dichlorinated chloride of methyl, and perchloride of formyl, was discovered by Dr. Samuel Guthrie, of Sackett's Harbor, N. Y., in 1831, and about the same time by Soubeiran, of France, and by Liebig, of Germany. Its real chemical composition was determined in 1834 by Dumas. Guthrie evidently obtained in a pure state the substance now known as chloroform, though he supposed it to be the well-known oily liquid of the Dutch chemists which it greatly resembled, and which was known as "Dutch liquid," or ethane dichloride. He therefore used the term chloric ether, thinking he had discovered a cheap and easy process for obtaining ethane dichloride.

Chloroform is a liquid consisting of from 99 to 99.4 per cent. by weight of absolute chloroform, and from 0.6 to 1 per cent. of alcohol. It is a compound of one atom of carbon, one atom of hydrogen, and three atoms of chlorine. It has a chemical formula of $C\,H\,Cl_3$. Its simplest theoretical derivation is from the action of chlorine on marsh gas (methane) $C\,H_4$, whence it has been called *trichlor-methane*. Practically, chloroform is produced from alcohol by the action of chlorinated lime, from alcohol by an alkaline hydrate, or, of late years, chiefly by the distillation of acetone with chlorinated lime.

Chloroform is a heavy, clear, colorless, volatile and diffusible liquid with an ethereal, penetrating odor, and a burning taste. Its sp. gr. should not be below 1.490 to 15° C (59° F.). It is volatile even at low temperatures, and boils at 60 to 61° C. (141 to 141.8° F.). It is not inflammable, but its heated vapor burns with a greenish flame.

Chloroform has marked solvent properties. It is soluble in 200 times its volume of cold water, and in all proportions in alcohol, ether, benzol, benzin, and in fixed and volatile oils. It is liable to decomposition by sunlight, and even by diffused daylight, hence should be kept in well-stoppered, colored glass containers.

Chloroform may contain alcohol and ether, both of which lower its sp. gr. If its density is less than 1.38 it will float instead of

sinking in a mixture of equal weights of concentrated sulphuric acid and water after it has cooled.

Absolutely pure chloroform is liable to decomposition, and a small amount of alcohol is necessary to preserve it. It is said that one-tenth of one per cent. is sufficient. It is claimed that when purified by Pictet's freezing process the presence of alcohol is not necessary to the preservation of chloroform.

There has been much discussion in regard to the presence of impurities in chloroform and their relation to dangerous symptoms or fatal conditions arising during the use of chloroform as an anæsthetic. There is no definite knowledge on this point, and as such symptoms and conditions arise from the use of chloroform of known absolute purity, it is not possible to be explicit in this connection.

Chloroform should have the sp. gr. and boiling point already mentioned. It should be transparent and colorless. It should be absolutely neutral to test-paper and its odor should be non-irritating.

If alcohol be present in chloroform it may be detected, according to M. Mialke, by dropping small quantities of chloroform into distilled water. If the chloroform is pure it remains transparent at the bottom of the glass, while if only a small per cent. of alcohol is present the globules will be milky. Soubeiran advised the agitation of chloroform and almond oil in a tube, when, if pure, the chloroform remains clear, while with 5 or 6 per cent. of alcohol it becomes milky.

The following official tests may be used: Pour 20 c. c. of chloroform on clear, odorless filter paper laid flat on a narrow glass or porcelain plate. Rock gently until chloroform is entirely evaporated. No foreign odor should remain, and the paper should be nearly odorless as compared with new, odorless filter paper; shake 10 c. c. of chloroform with 20 c. c. of distilled water and allow complete separation. The water should be neutral to litmus paper and should not be affected by silver nitrate test-solution (absence of chlorides), or by potassium iodide test-solution (absence of chlorine); place about 5 c. c. of chloroform in a test tube with a capacity of about 10 c. c., add about 4 c. c. of perfectly clear barium hydrate test-solution without agitation, cool the test-tube and set aside in a dark place for six hours. No film should be visible

at the line of contact of the two liquids (absence of products of decomposition in chloroform which may otherwise be pure).

There are other tests and methods of purification which are not necessary to consider here, as reliable manufacturers now furnish a pure article of chloroform.

Physiological effects and action.—The inhalation of chloroform vapor is not as unpleasant as the inhalation of ether. Its odor is rather agreeable than otherwise, while the taste is pungent and sweetish.

During the first stage there is little sense of suffocation unless the vapor be too concentrated. Swallowing, choking, and holding the breath usually do not occur unless the vapor be strong enough to irritate the larynx. There is a general feeling of warmth and exhilaration, pressure and fullness in the head, noises in the ears and similar effects common to the initial stage of anæsthesia by other agents. The breathing is somewhat deeper and quicker. The pulse is quickened and full. The pupils are usually somewhat dilated. The first stage is short compared with that of etherization, and may be devoid of symptoms other than the deeper, quicker breathing, and the more rapid pulse.

The second stage is marked by flushed or pale countenance, irregular, jerky respiration, a greater or less degree of excitement, especially in muscular, alcoholic, nervous or hysterical subjects. Talking, shouting, swearing, gesticulating, attempts to rise, movements of the arms and legs, holding of the breath, etc., are not uncommon. The patient may be easily aroused at this period, though sensibility to pain is decidedly lessened. The sense of taste and smell are abolished, though that of touch may remain. The sense of sight may be abnormally acute or may be subject to illusions. In some cases none of these symptoms are present, and the patient passes gradually and gently on to complete unconsciousness. Muscular rigidity may or may not be marked. It is most frequent in muscular or alcoholic subjects. Tonic or clonic spasm may occur. Fine tremor is rare. Holding the breath, tonic or clonic spasm may occur from too rapid administration. Struggling or excitement, on the other hand, may result from too rapid administration. A proper medium may direct the patient on to the quiet, easy, snoring respiration of full anæsthesia. In exceptional cases the respiration is rapid and deep

throughout this stage. There may be loud stertor, which, however, does not indicate deep anæsthesia. The pulse varies greatly. It may be very slightly accelerated, regular and soft. Again, it may be rapid. The rate, regularity and fullness of the pulse depend largely on the conditions arising during the administration. Interference with respiration from any cause, coughing, vomiting, etc., will produce variations in the pulse. The pulse may become quite small and feeble and slow just preceding the act of vomiting. Syncope may occur from vomiting. The probability of its occurrence and its dangers are less in vigorous subjects. The pupils are usually more or less dilated, and react slowly or not at all to light. They may be moderately or decidedly contracted Movements of the eyeballs may occur from spasm. Nystagmus may be present.

The respiration, instead of gradually acquiring the regular character of full anæsthesia, may become shallow or imperceptible, and be accompanied by pallor and feeble pulse. Hewitt considers this condition a result of too sparing administration and an indication of a tendency to vomit, and that it could be obviated by a careful continuance of the anæsthetic. In some instances this is probably the case, and in others these symptoms are indications of failing respiration. In some cases, especially in children, there may be all the appearances of complete anæsthesia and yet sensation may not be abolished. This is liable to occur if a patient is kept for some time under chloroform before operation is begun, and under these conditions dangerous, reflex, respiratory spasm or cardiac syncope may develop.

In some cases the patient may not exhibit the respiratory or other signs of complete anæsthesia, may answer direct questions, repeat words, or even have an indistinct realization of what is going on and yet be sufficiently insensible to pain as to submit to operation without complaint. The corneæ at this time may be insensitive, though the lid-reflex can generally be obtained.

THE THIRD STAGE of chloroform anæsthesia is usually marked by regular, soft, slightly snoring respiration. The face may be slightly flushed or pale. Pallor may be shown if there is a tendency to vomit. Slight obstructive interference with breathing may cause slight cyanosis. Usually cyanosis is absent, as plenty of air is allowed during this stage of the administration. The face

usually becomes pale after the administration has been continued for some time. There is usually complete muscular relaxation. Rigidity at this stage is rare. There is slight reduction of the body temperature. The secretion of mucus and saliva is rarely sufficient to cause annoyance. The eyeballs may be fixed in the horizontal plane or may be slowly movable. As a rule the movements are not co-ordinate. Loss of associated movement may be an indication of complete anæsthesia. The pupils are usually contracted. They are decidedly smaller than the ether pupil, measuring on the average, according to Hewitt, 2½ mm. They are more or less responsive to light, and react to the anæsthetic. A dilated pupil may indicate returning consciousness or may indicate increasing narcosis. The lid-reflex, as a rule, is absent, though there may be exceptions to this rule.

The pulse is generally well sustained under properly conducted administration. It is slower than under etherization, as a rule, and may be at the normal rate or even considerably less. The pulse tension is diminished, and in weak subjects the pulse may be feeble or almost imperceptible, though here the pulse is usually stronger during deep anæsthesia than during the second stage. Retching, vomiting, and respiratory disturbances affect the pulse, causing it to become more feeble and sometimes irregular. A markedly slow pulse may indicate too deep anæsthesia. A normally slow pulse will usually continue slow under deep anæsthesia. Kappeler states that in twenty patients of various ages the decline in pulse rate varied from four to thirty beats per minute. There is a more or less rapid and maintained fall of blood pressure.

In some cases the respiration, while satisfactory, will be quiet and inaudible. There may be loud stertor, especially in plethoric subjects, if the anæsthetic be pushed. Inspiratory, laryngeal stridor may be present. The breathing generally is more quiet, less deep, and its general character less evident than with ether, therefore it is not as reliable a guide under chloroform as under ether anæsthesia.

The toxic effects of chloroform inhalation are shown by marked pallor, cold perspiration, feeble or imperceptible pulse and very shallow respiration. The respiration may stop suddenly or gradually. The pulse may show signs of failure before it ceases, or an apparently good pulse may stop suddenly without warning.

The pulse usually stops before respiration ceases, or at least becomes affected before respiration. Death may occur soon after the beginning of the inhalation, and at that time is probably due to paralysis of the cardiac ganglia, which for unknown reasons may be abnormally susceptible. Death may occur in the stage of muscular rigidity which precedes complete muscular relaxation, and be due to tetanic rigidity of the respiratory muscles, interference with the pulmonary circulation, and venous engorgement of the right side of the heart, respiration ceasing before the heart.—Richardson's *epileptiform syncope*. This difficulty is not so liable to arise under chloroform as under the open methods of etherization. Death may occur from respiratory paralysis during the stage of relaxation, though this is not common from chloroform. Cardiac paralysis may occur during complete insensibility from paralysis of the motor ganglia. The heart suddenly stops, respiration continuing for a short time. General depression from the anæsthetic, plus surgical shock or the shock of accident, may result in death at the time of the inhalation or afterward.

The physiological action of chloroform is more energetic and prolonged upon protoplasm than is that of ether. Waller's estimate of the relative toxicity of ether and chloroform upon isolated nerves is as 1 : 7. Locally, the action of chloroform is irritant. It destroys the contractility of muscle tissue, causing "chloroform rigidity." It produces structural changes in muscle tissue (Bernard). It is solvent to the essential ingredient of nerves and nerve centers (Brunton).

The subcutaneous injection of chloroform has a local anæsthetic effect, but owing to slow absorption and free elimination general anæsthesia is not produced. The latter state may be produced by intravenous injection. Snow has calculated that the blood of the adult necessarily contains from 12 to 24 minims of chloroform, according to the degree of anæsthesia, and for the arrest of respiration 36 minims are necessary. It has been found that with atmospheres containing from 2 to 4 per cent. of chloroform there is little risk, but with above 5 per cent. there are alarming symptoms.

The respiratory center is first stimulated by chloroform, this is followed by depression and finally by paralysis. The depressing effect of chloroform on respiration is more marked on expira-

tion than on inspiration. Beside the toxic effect of chloroform on the respiratory center, we have to consider, in respiratory failure from chloroform toxæmia, the additional factors of loss of blood pressure from cardiac depression, and the effect of obstructive interference with respiration.

In regard to the respiratory interchange of gases under chloroform, there is less oxygen absorbed and less carbonic acid exhaled, though according to some observers there is increase in the amount of the latter.

The blood changes due to chloroform are not definitely understood. It is generally conceded that there is diminution in the capacity of the blood to absorb oxygen and to give off carbonic acid. Also that there is some degree of disintegration of the red blood cells.

The effect of chloroform on the blood-pressure and heart has received much attention, which has resulted in diverse opinions. The Committee of the Royal Medical and Surgical Society, Gaskell and Shore, and MacWilliam in some instances, found a primary rise, followed by a fall, in blood-pressure. The Glasgow committee found a fall in blood-pressure, while Wood and Hare found an initial fall, followed by a rise, in blood-pressure. Most observers agree that the fall of blood-pressure is due to the effect of chloroform on the heart and not to its effect on the vaso-motor center.

The effect of chloroform on the heart itself has caused much discussion. The views of the Hyderabad commission to the effect that not only was the primary fall in blood-pressure due to the effect on the vaso-motor center, but that the heart was never primarily affected, is generally disregarded at present. The observations of Wood and Hare, Gaskell and Shore, Hill and Barnard, MacWilliam, and others, tend to show that chloroform directly depresses the heart, and that when respiration ceases before final stoppage of the heart the primary depression of the heart's action is the essential and probably the initial factor in death from chloroform. Experiments on animals show that chloroform produces dilatation of the heart. Physiologists claim that reflex temporary inhibition of the heart by irritation of the nerve endings in the upper respiratory tract by chloroform is not generally dangerous, and may even be in a sense conservative. Phys-

iologists also state that chloroform injected into the veins depresses the heart, and injected into the carotid arteries causes paralysis of the respiratory and vaso-motor centers. Hill has shown that when a chloroformed subject is changed from a horizontal to an upright position there is a greater fall in arterial pressure than would occur without chloroform. This has a direct bearing on the question of posture, and the moving of chloroformed subjects.

Salivary secretion is usually slightly increased during the early stage of chloroform inhalation and diminished during deep anæsthesia.

Chloroform affects the kidney action much less than ether. The kidney secretion is generally fair unless there is marked depression of the circulation. Albuminuria is rare except after prolonged narcosis.

The repeated administration of chloroform to animals produces fatty changes in various organs and tissues.

After death from chloroform the heart will usually be found somewhat dilated and the right cavities full of blood, the left side being comparatively empty. If death has occurred after a gradual administration without any asphyxial element, the heart may be relaxed and empty, and the lungs not especially congested. If death occur after marked asphyxial conditions there will be marked congestion of the lungs, overdistention of the right heart, with but little blood in the left side. In cardiopathic subjects death may occur before marked alterations, due to the administration, take place. If arrest of respiration occurs during or at the end of inspiration the lungs will contain more blood than when such arrest occurs during expiration (Hill). According to Kunkel, the heart arrested by chloroform always stops in diastole. Various observers state that the blood after death from chloroform is of a deep cherry color, and more fluid than usual. According to Fränkel and others, the tissue elements of the heart, liver and kidneys undergo coagulation necrosis, and there are deposits of pigment in the parenchyma of the kidneys and liver.

The after effects from chloroform inhalation vary considerably, according to the nature of the administration and the character of the symptoms during the period of inhalation. When the administration has been properly and carefully conducted and

the subject has taken the anæsthetic without difficulty, the recovery will be uneventful, the patient passing into a quiet sleep, possibly preceded by slight retching or vomiting. If the chloroform has been exhibited with too much conservatism or there has been unpleasant manifestations during its inhalation, there may be marked pallor, weak pulse, nausea, or vomiting. Gastric disturbance is more frequent after ether than after chloroform, but the vomiting of the ether is more transient and less liable to recur than that occurring after chloroform. Severe and prolonged vomiting is more common after chloroform. Depression of the circulation is a more common after effect from chloroform than from ether.

Bronchial inflammation and pneumonia are rare after chloroform, though they may occur in predisposed subjects. Mental disturbances may occur in predisposed subjects. Jaundice may be a rare after-effect. Some observers have claimed that albuminuria is frequent after chloroform, but this is not generally conceded. L. G. Guthrie believes that a condition similar to acute yellow atrophy of the liver may be a fatal after-effect in children.

The dangers arising during chloroform administration may be due to the toxic action of the drug, or may be such as arise during the administration of any anæsthetic. More or less danger may result from obstruction of the breathing, from nervous arrest of respiration in excitable subjects, or from obstruction due to spasm, swelling of the upper respiratory tract, or obstructive interference of the tongue, though such causes are infrequent under chloroform. Spasm of the respiratory muscles, foreign substances in the air tract, as enumerated under ether (p. 120), may cause danger. Vomiting is not frequent, but dangerous vomiting is relatively more frequent under chloroform than under ether. Interference with lung expansion from tight clothing, the posture, morbid states, respiratory spasm, and interference with lung expansion through operative measures may cause danger. Paralytic arrest of breathing may occur from too large a dose of the anæsthetic, from reflex inhibition from operative measures, from cerebral anæmia, and it is claimed in part from morphine administered previous to inhalation.

Failure of the circulation may result from such predisposing causes as morbid conditions of the heart, lungs, blood, renal dis-

ease, mental disturbance, sitting posture, food in the stomach, or from respiratory embarrassment from various causes, vomiting, the operation, or from the effect of chloroform on the heart and vascular system.

The clinical evidence regarding chloroform gathered by the Anæsthetics Committee of the British Medical Association (1900) is to the effect that chloroform is about twice as dangerous in males as in females; it is most dangerous during infancy, and least dangerous from the tenth to the thirtieth years; chloroform is the most dangerous anæsthetic in conditions of good health, and while least safe in grave conditions, the disparity here is less marked. When danger occurs from chloroform, in the large proportion of cases the symptoms are of primary circulatory failure. Imperfect anæsthesia is the cause of danger in a large number of cases. Hewitt calls attention to the important fact that a large proportion of the conditions of danger during chloroform administration are not connected with an overdose, relatively speaking, of the anæsthetic. He finds that of 130 chloroform deaths reported in the *Lancet*, and *British Medical Journal*, from 1880 to 1889, inclusive, 54 took place very early, either before operation or during short or trivial operations. Comte collected 232 cases of death. The time of death was specified in 224 instances, and in 50 per cent. occurred before anæsthesia was complete. Hewitt combines 101 cases given by Kappeler and 109 cases reported by the Committee of the Royal Medical and Chirurgical Society in 1864, and finds that the time of death was specified in 75 cases, in 90 per cent. of which death occurred within the first fifteen minutes. The report of the Anæsthetics Committee of the British Medical Asssociation (1900) gives 13,393 chloroform cases in which complications of some degree arose in 3.270 per cent. There were 120 dangerous cases, with 18 deaths. The combined statistics of Gurth, of Berlin, and Juillard, of Geneva, give 691,329 cases of chloroform inhalation, with 224 deaths. Chloroform is generally regarded as being about five times as dangerous as ether.

There are various factors which constitute a source of danger during chloroform inhalation besides the toxic action of the drug itself. Psychical causes may contribute towards danger or death early in the administration. Cases have been reported by various observers of death apparently due to fright alone before the ad-

ministration had begun. It is a fact, however, that the cases of "fright syncope" are practically limited to cases where chloroform was employed, and we must therefore regard psychical influences as merely a more potent contributory cause under chloroform than under other anæsthetics. Reflex cardiac inhibition from the effect of concentrated vapor on the mucous surface of the upper respiratory tract was a favorite theory of French observers as to the cause of early manifestations of danger. It is not generally admitted that this cause is effective. Holding the breath, laryngeal spasm, and asphyxial conditions from irritation by the vapor are probably rare, being in most instances due to obstruction or to the effect of the agent on the respiratory center or on the muscles of respiration. It is generally believed that shock due to the commencement of operation may produce dangerous or fatal syncope. Hewitt believes that such a cause rarely is fatal, if ever, and calls attention to the fact that skin incisions under light anæsthesia almost invariably stimulate both respiration and circulation. Nevertheless, many observers have found signs of collapse coincide with the beginning of operation.

In the list of fatal chloroform cases given in the report of the British Medical Association Committee already alluded to there are some instances where the pulse and respiration failed either coincidently or successively at the moment of the beginning of operative procedures.

Reflex arrest of respiration from spasm is more likely to occur under chloroform during surgical measures than with other anæsthetics. Vomiting may cause depression of the heart and possibly fatal syncope. Dangerous vomiting during anæsthesia is said to be more frequent under chloroform than other anæsthetics. Epileptiform spasm may be dangerous, especially in muscular subjects. Clonic spasm is not uncommon early in the administration, which may indicate a need for more anæsthetic. Clonic movements of the arms and pectoral muscles indicate a necessity for more air (Hewitt). Laryngeal spasm, shown by high-pitched inspiratory stridor, may occur during anæsthesia by chloroform, apart from the local effect of the drug as a cause. It is thus more common under chloroform than under ether, and represents a dangerous degree of anæsthesia.

Pathological states, posture, idiosyncrasy on the part of the

patient, and late surgical shock may all be factors in the production of dangerous symptoms.

Chloroform toxæmia from an overdose may result through too concentrated vapor, exaggerated breathing of vapor not unusually concentrated, and through some unusual susceptibility on the part of the subject. The result may be simultaneous stoppage of both pulse and respiration, or the pulse at the wrist may stop before respiration ceases, or the pulse may be still perceptible when respiration ceases. In pure chloroform toxæmia the respiration ceases before the heart action. We may not be able to feel the radial pulse or even to hear the heart beat if the lungs are full of air. This does not prove, however, that the heart has actually stopped. The failure of heart action is the primary and essential feature of death from chloroform toxæmia. If this condition should supervene upon a carelessly rapid administration, death may come too suddenly to allow of any recognition of the sequence of the symptoms. Toxic conditions following a more gradual administration show shallow, slow, gasping, jerky or irregular respiratory action with cessation of abdominal and thoracic movements. The symptoms which indicate the approach of toxæmic conditions are: impaired respiration, slow, feeble pulse, becoming irregular and often imperceptible; no lid-reflex; separation of eyelids; upturned eyeballs; considerable or marked dilatation of the pupils; marked pallor of skin.

Deaths from chloroform are marked by sudden heart failure following upon respiratory interference, which may in some instances be comparatively slight; and by toxæmic conditions of the cardiac nervous mechanism, or possibly in some degree of the myocardium itself.

For the administration of chloroform the patient should be in the recumbent position; the sitting position should not be used if it can be avoided. The patient should not be moved or the position changed after administration is begun unless absolutely necessary. The patient should be reassured, informed as to the nature of the sensations produced by the inhalation, and instructed how to breathe.

The administration of chloroform may be conducted by administering the vapor of chloroform with air or with oxygen. The latter method was introduced by Neudorfer, of Vienna, who

administered mixed oxygen and chloroform vapor through a closely fitting face-piece. Junker's inhaler has also been used by pumping oxygen from a bag attached to the hand bellows through the chloroform. This method of administering chloroform has not been much used and is of doubtful advantage.

The toxic nature of chloroform demands that it should be administered with plenty of air, and that any method or apparatus employed for its administration should afford ample facility for the admission of plenty of air at a moment's notice. Simpson, who introduced chloroform as an anæsthetic, used a handkerchief folded in a cup-shape, into the hollow of which a small amount of chloroform was poured. Later he employed a folded cloth or towel, and still later a single layer of cloth laid over the patient's mouth and nose, upon which the chloroform was dropped. This method corresponds to the drop method used with the Esmarch or Skinner mask, so widely in use at the present time.

Snow's experiments with definite amounts of chloroform vapor led him to devise an inhaler by which the percentage of chloroform vapor could be regulated at about 4 or 5 per cent. Clover

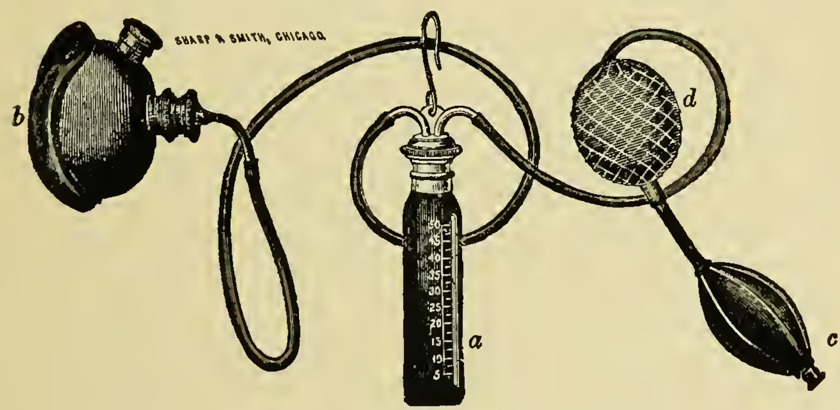


Fig. 33.—Junker's Inhaler.

Fig. 33. An anæsthetic bottle (*a*), which is connected by rubber tubes to the face-piece (*b*), and an air bellows (*c*), to the latter of which is attached an equalizing rubber ball (*d*), covered with netting, to prevent over-distension.

The anæsthetic bottle is graduated, so that the amount of the anæsthetic consumed is known. To the stopper of the bottle there is a hook attached, by which it may be hung from the anæsthetist's coat.

also devised an inhaler which would give from $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent. of chloroform vapor. Many other inhalers have been devised along these lines. They have the objection of a closely fitting face-piece, which adds to the dangers of producing complete anæsthesia by their use. The Junker inhaler, which has been much employed, especially in England (Fig. 33), consists of a bottle to contain chloroform, a loosely fitting face-piece, a hand bellows, and tube connections. Air is pumped through the chloroform in the bottle and into the face-piece, carrying with it an indefinite percentage of chloroform. A cloth mask may be used instead of the ordinary leather or vulcanite face-piece, which will allow of dropping chloroform on the mask if a more concentrated vapor is necessary. The Junker inhaler is not a safe inhaler for children, and though when carefully used it may lessen the risks from chloroform inhalation, several deaths have occurred under its use. Hewitt has modified the Junker inhaler to some advantage. Such an apparatus as the Junker may be very useful in operation's about the mouth, nose, or pharynx, where, especially if the actual cautery is to be used, ether is not available. In these operations the vapor may be introduced through a nose or mouth-tube, such as Hewitt's modification of Mason's gag. In such operations the advantage of such inhalers is most evident. In ordinary surgery they demand too much attention, the constant pumping is troublesome, asphyxial conditions are as liable to arise as with other methods of administration, and in some cases profound anæsthesia cannot be induced.

Many kinds of inhalers have been devised. There are combination inhalers, like the Packard inhaler or the Bennett inhaler, that may be used for either gas, ether or chloroform; or inhalers like Hiddens' that are only suitable for chloroform.

That the simplest method of administration is the best is a more forcible truth in relation to chloroform than any other anæsthetic, for the reason that any inhaler other than the very simplest is objectionable. The method which will produce a satisfactory analgesia with the least amount of chloroform is the best, and this can undoubtedly be accomplished by the drop method on a mask or a single layer of cloth or lint. This is practically the method of Simpson, improved. Simpson at first considered chloroform as a perfectly safe anæsthetic, and recommended it to

be used "powerfully and speedily," in order to avoid excitement. Later he modified his method more in accordance with present usage.

The difficulty of estimating the percentage of chloroform inhaled in this method has been considered its weak point. Snow, who estimated that the inhaled vapor should not exceed a strength of 5 per cent., calculated that 9.5 per cent. might be given off from a folded cloth wet with chloroform at 70° F. Lister estimated that a moistened cloth held close to the face gave off but 4.5 per cent. Sansom claimed that at 60 to 64° F. it was possible to inhale 13 per cent. of vapor with but one dram of chloroform poured upon lint. That it is practically impossible to estimate the percentage of vapor inhaled is evident when we consider the nature of the fabric used, the number of its folds, the extent of

Fig. 34.—Esmarch's Inhaler.

Fig. 34. A simple with frame shaped to fit the contour of the face around the mouth and nose; one end of the frame is curved to form a handle by which the apparatus may be held in place. Over this framework is stretched a knitted or woven fabric, the texture of which is of such a nature as to admit of the free passage of air. The chloroform may be dropped upon the mask from a small flask containing a cork through which a suitable drop tube is passed. This tube reaches nearly to the bottom of the bottle and is curved so that all of the chloroform in the container may be dropped from the tube. The mouth of this drop tube is closed by a suitable cap that the chloroform vapor may not escape from the flask when not in use. Air to replace the chloroform is admitted by a second tube also passing through the cork.

surface wet with chloroform exposed to the air, the proximity of the fabric to the patient's mouth and nose, the temperature of the air, the movement of air about the inhaler, and the rate and force of the patient's breathing. That Lister recognized the uncertain element of a large surface of several folds of cloth is shown by his adoption of the method of drawing the corner of a towel through a safety-pin in such a way as to form a cup-shaped inhaler, practically the same as the Esmarch inhaler.

With any inhaler which embodies the principles of the mask, or the drop method, it is possible to graduate the percentage of

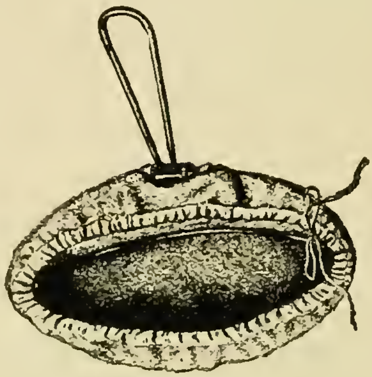


Fig. 35.—Skinner's Mask.

vapor inhaled so as to secure the most effective narcosis with the least element of danger, and with a comparatively small amount of chloroform.

A thin napkin, a piece of lint, or a single layer of a moderately heavy handkerchief may be stretched across the separated thumb and forefinger of the administrator and held close to the subject's mouth, or it may be laid across this and a space an inch and a half square kept moistened with chloroform. A corner of towel drawn through a safety-pin makes a very convenient mask for inhalation. The Esmarch inhaler (Fig. 34) may be used with a single layer of gauze, cotton cloth, or flannel, but in very warm weather it is well to have a heavier material or two layers of light cloth. The Skinner mask (Fig. 35) is a similar form of inhaler. In using lint Hewitt recommends making a concave fan-shaped mask by folding once over a piece of lint 11 inches long by 7 inches wide so that when folded it measures 7x5½ inches. Pinch

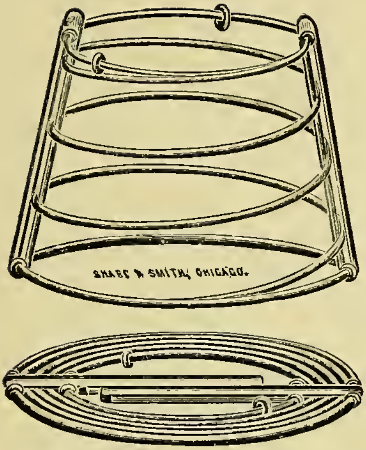


Fig. 36.—Pierepont' Folding Chloroform Inhaler.

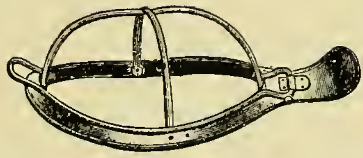


Fig. 37.—Schimmelbusch-Esmarch Inhaler.

Fig. 38.—Plain Ether Drop Bottle

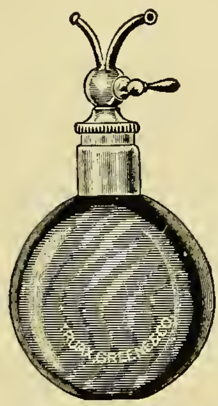


Fig. 39.—Hahn's Drop Bottle.

up the free double edge between the fingers and run a safety-pin through the gathered edge.

In using the drop method and mask inhaler one may employ the graduated 2-ounce bottle with spring stopper arrangement for dropping the chloroform (Figs. 38, 39), or, if this is not at hand, an ordinary 2-ounce bottle may be used. A longitudinal trough is cut in the cork of a sufficient depth and width to accommodate a couple of strands of cotton twine, which should be long enough to reach well into the bottle and a couple of inches outside. When the bottle is tightly corked the cotton acts as a wick and the chloroform can be shaken from the end of the string or the string can be trailed across the mask, thus supplying the chloroform as fast as may be desirable. In some instances it is necessary to administer an anæsthetic through a tracheal opening. For such cases Annandale uses a full-sized tracheotomy tube, with its upper end extended one-half inch above the shield (Fig. 40). It is fitted with a cap having a right-angled tube connection, which may be connected by a rubber tube with a glass containing the chloroform or ether upon some cotton wool. Chloroform is the agent preferred. The chloroform is held directly over the mouth of the tube until the patient is anæsthetized. The cap is then placed on the tube and connected with the rubber tube and the administration continued.

In administering chloroform the mask should not be held close to the face at first, and only a few drops of chloroform should be used, but after the first few inhalations the mask should be brought closer and its surface kept wet. If there is choking, coughing, or holding the breath the mask may be lifted but not entirely withdrawn. The administrator should endeavor to maintain the happy medium between too much and too little chloroform. If too little is given, coughing, swallowing, holding the breath, struggling and vomiting may occur, and may be prevented by more chloroform. With some subjects it may be necessary to keep the mask wet most of the time, especially in vigorous or alcoholic patients. In children much less will usually be required. The average quantity for an ordinary adult will be from 10 to 16 drachms for the first hour, and less as the administration lengthens.

It has been claimed that syncope is liable to occur from too

marked intermittance in the administration. Incomplete anæsthesia appears to be associated with complications of all degrees of severity, much more so under chloroform than under ether. Vomiting, which is often an evidence of incomplete chloroform anæsthesia, may be the starting point of other complications of both the respiration and circulation.

It is very important that the requisite degree of anæsthesia should have been reached before the operation commences, and that this should be maintained during the operation. Attempts to hasten the recovery from the anæsthetic by shaking the patient or flipping with a towel should not be made.

Children are very sensitive to the irritations of chloroform

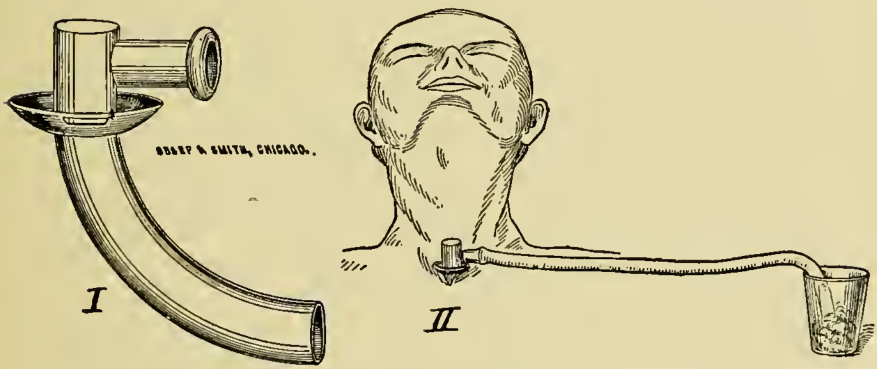


Fig. 40.—Annandale's Trachea Canula and Tube.

Fig. 40. A full-size silver tracheotomy-tube, with its upper end extended about ½ in. beyond its shield, is employed. There is a silver cap having a short tube of silver projecting at right angles, and to the small end of this cap a rubber tube can be connected. Fig. 40-I shows the tracheotomy-tube with the cap fitted upon it. This cap can be turned to either side, thus permitting the India-rubber tube to project on the side which will be most convenient to the operator. India-rubber tubing of the diameter of about ½ in. is used. One end of this tube is fastened to the apparatus; the other end is placed in a tumbler containing a small piece of absorbent wool at the bottom, upon which chloroform or ether is from time to time sprinkled. The whole apparatus is shown in Fig. 40-II. Annandale prefers to use chloroform. In beginning the administration the cap is taken from the tracheal tube, and the chloroform is held directly over the tube until the patient is anæsthetized, but when the time for operation has come the cap is put in place and the anæsthetic is given as shown in Fig. 40-I. In order to prevent blood or vomited matters entering the air-passages, it may be advisable to introduce a piece of sponge into the trachea above the tracheotomy-wound.

vapor. They are likely to hold the breath at the beginning of inhalation or after unconsciousness is reached. Very little chloroform should be used at first, and the mask should be approached to the face cautiously. If the child cries the inhalation is more rapid and the mask should be withdrawn immediately there are indications of ceasing to cry. Immediately after the crying stage children may pass into an apparent state of anæsthesia with contracted pupils, insensitive corneæ, relaxed muscles, feeble pulse, and irregular respiration. The chloroform should be stopped, the lips briskly rubbed with a dry towel, and the child otherwise stimulated. A little ether administered on the mask may cause immediate improvement in both pulse and respiration.

Children may be chloroformed while asleep by holding a mask several inches above the face and allowing a drop of chloroform at a time to be inhaled, approaching the mask to the face very gradually. Children are favorable subjects for chloroform by reason of their freedom from diseases of the heart, lungs, or kidneys. Nevertheless, chloroform is not so free from danger in children as many suppose. This has been attributed to the fact that their reflex action is more excitable and more quickly abolished by anæsthetics. Corneal and conjunctival reflexes are not, therefore, as reliable as in the adult.

As the patient comes fully under the anæsthetic the breathing will be regular and audible with soft snoring. Swallowing movements may be present, and if slight may be recognized by the fingers on the larynx. They may indicate recovery from the anæsthetic and a necessity for more. Absence of lid-reflex is an important sign of anæsthesia, but is not as reliable a guide as in etherization. Whether or not the administrator should strive to keep the lid-reflex abolished will depend on the manner in which the patient takes the anæsthetic, and on the nature of the operation. In weak or elderly people, and in short operations it is not necessary or advisable to completely abolish lid-reflex, while in robust subjects, or in abdominal operations it is generally necessary to do so.

The pupils will average a greater degree of contraction than with ether narcosis. A dilated pupil is a guide to returning consciousness except when it is due to too deep narcosis. A few

drops of chloroform given when the pupil is dilating from recovery, is followed after a few respirations by contraction. The delay in this action makes it important that one should be certain as to the cause of the dilatation before administering more chloroform. If the dilatation is associated with conjunctival reflex it may be taken to indicate more chloroform. If it is associated with absence of conjunctival reflex it may indicate less chloroform until contraction or reflex appears.

The color of the face, usually somewhat flushed at the beginning, becames more or less pale. Marked pallor is usually indicative of poor circulation though this is not always the case. Cyanosis always indicates a need for more air. Pallor with light anæsthesia may indicate the approach of vomiting.

The respiration is generally considered to be the most important guide to the state of the anæsthesia. Some anæsthetists claim that the respiration should be the guide first, last, and all the time. The administrator should try to maintain the soft, regular, snoring breathing. Withdrawal of the chloroform usually results in quiet, inaudible breathing, while increasing the chloroform may cause increased stertor. When snoring cannot be heard it may often be produced by pressing the lower jaw backward. In some cases the breathing may be inaudible and yet absent lid-reflex, a moderate contraction of the pupils, and muscular relaxation will testify to complete anæsthesia. On the other hand, in order to not mistake absence of stertor for too deep anæsthesia, one must watch for slight lid-reflex, expiratory noise, swallowing, or slight tonic muscular spasm, contracted pupil, and absence of pallor as indications of too light anæsthesia.

In some cases the amount of chloroform necessary to obtain the requisite degree of anæsthesia will produce shallow, inefficient respiration with moderate cyanosis and slow, regular pulse. The patient can be usually roused from this condition by friction of the cheeks and lips with a dry towel.

High-pitched inspiratory laryngeal stridor may necessitate withdrawal of the anæsthetic. Cheyne-Stokes breathing may be present in weak subjects under deep anæsthesia and indicate a too deep narcosis or a change to some other anæsthetic.

The pulse should be observed from time to time. It often

becomes weak just before vomiting. After anæsthesia has been established with a regular, slow pulse, changes in the pulse, if the corneal reflex is absent, are of importance. A slow, feeble pulse with absent lid-reflex indicates less chloroform. It is well to observe the facial, temporal, and superior coronary pulse, as, at times, a better idea can be obtained from these vessels of the state of the circulation.

It has been the experience of some administrators of chloroform, that while conducting the administration in a small, illy-ventilated room artificially lighted by a naked flame, they have become affected with more or less severe irritation of the air passages, dyspnœa, coughing or faintness. This may affect everybody in the room including the patient, but more often the administrator only is the one to suffer. Zweifel has reported a fatal case of bronchitis and pneumonia attributed to this cause. Iterson, Fischer and others, have reported on this peculiarity of chloroform. That the fumes are acid is apparent from the fact that they may be neutralized by the liberation of ammonia in the room by suspending cloths saturated with the alkali. It is claimed that the irritation is due to the formation of phosgene, and hydrochloric acid gases. Bréandat claims that the combustion of chloroform gives rise to hydrochloric acid, and an acrid and acid oil.

The management of the complications incident to the administration of chloroform. The management of the more common difficulties such as excitement, spasm or movements, nervous or obstructive interference with respiration, coughing, hiccough, sneezing, vomiting, foreign bodies in the air passages, mucus or saliva, the effects of posture, laryngeal spasm, general spasm of the respiratory muscles, etc., is along the same lines as when they occur under etherization (P. 119, et seq.).

Respiratory arrest from an over dose of anæsthetic usually occurs gradually, the breathing becoming more and more shallow, though in some cases it may be jerky, gasping, and irregular. In rare instances the breathing may stop with great suddenness. Feeble, shallow respiration is not important as long as the pulse and color are good and the lid-reflex is maintained. When the breathing shows signs of arrest the anæsthetic should be stopped, friction of the lips and cheeks used, and rhythmical

pressure of the chest or sternum made with each expiration. The inhalation of oxygen is useful, though regarded indifferently by many. Ammonia to the nostrils, or ice in the rectum may be used. Flicking the chest with a wet towel is sometimes practiced.

If the respiration stops entirely as shown by cyanosis, absence of all movements of the thorax or abdomen and no air movement from the mouth or nose, artificial respiration should be resorted to at once. This is regarded by many as the only means of any great promise. Sylvester's method, or Marshall Hall's method may be used, the former preferred. In using Sylvester's method the patient is drawn along the operating table till his head is extended over its end, or he is placed crosswise on the bed in a similar position. If the patient is sitting he should be laid on the floor and the shoulders sufficiently elevated to allow of extension of the head. A mouth gag and tongue traction may be used in order to be sure that no obstruction to free breathing exists. The administrator stands or kneels at the patient's head and grasping his arms at the elbows presses them firmly against the sides of his chest for 2 or 3 seconds, then brings them toward the operator, extending them in the long axis of the patient's body for 2 or 3 seconds. The manœuver is then repeated at the rate of about 15 times a minute. Artificial respiration should be persisted in for sometime as recovery may follow its continued employment.

Marshall Hall's method is performed by placing the patient face downward on the table or floor with a pillow or folded quilt under his chest and one arm under his head. He is gently rolled on his side and back again about 15 times a minute, pressure being made on his back when he is in the prone position.

There are other methods but these are most commonly employed. Inflation of the lungs by mouth to mouth inflation, or by bellows, or by the Fell-O'Dwyer apparatus may be of benefit (Figs. 41, 42).

Faradism of the phrenic nerves may be used. Duchenne demonstrated its action in causing contraction of the diaphragm. The electrodes may be placed over the lower end of the scalenus anticus muscle, and the outer edge of the sterno-mastoid muscle which should be drawn inward. The current is turned on

for a few seconds causing contraction of the diaphragm. Expiration may be assisted by compression of the thorax and abdomen. The application of electricity to the region of the diaphragm has been effective in some cases. Respiratory failure from cerebral anæmia demands the same measures, together with inversion of the body. Drugs are of questionable value in these cases, but should be used while more active measures are being tried, especially in those most dangerous cases where the heart and respiration fail together. Strychnia is the most effective drug. It is recommended by H. C. Wood in these conditions as a respiratory stimulant. It should be given hypodermically in doses of from one-thirtieth to one-twentieth of a grain with or without brandy.

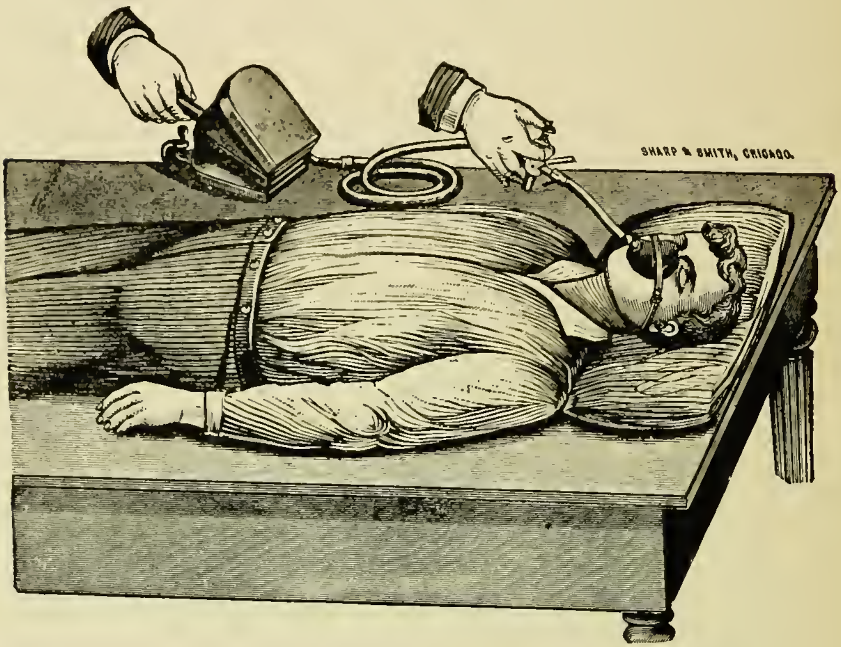


Fig. 41.—Fell's Apparatus for Lung Inflation.

Fig. 41. Fell's apparatus consists of a hand bellows connected by a suitable hose with an air-control valve and face-shield.

By properly working the bellows while making finger pressure on the valve, the lungs may be filled to their full capacity, after which the air is permitted to escape by natural means by releasing the pressure. For the next inspiration, pressure with the fingers is again made.

Depression of the circulation from general or local diseases, mental states, posture, food in the stomach, vomiting, or asphyxial causes during or after operation from spasm of the larynx. etc., are managed as in anæsthesia of any kind. In failure of the circulation from surgical shock or hæmorrhage the head and shoulders should be lowered, a hot water or alcoholic enema given, strychnia injected, saline intravenous injection given, and warmth to the body used.

The pulse may show primary failure suddenly or gradually. When the administrator is satisfied that the trouble is primarily with the circulation he should stop the anæsthetic, use friction of the face and lips, partially invert the patient, use artificial respiration, inject strychnia, digitalin, strophanthin, ether, etc. When the circulation is so weak that there is no bleeding from the wound the anæsthetic should always be stopped. If the pulse is not perceptible, a mouth gag may be introduced, tongue traction made, artificial respiration, partial or complete inversion, rhythmical compression of the chest, percussion of the præcordial area with the tips of three fingers about once a second may all be tried. Electricity, like drugs, is of doubtful value, and should be given over to an assistant, the administrator devoting his time to posture, artificial respiration, compression of the chest, etc. Electricity may be applied to the region

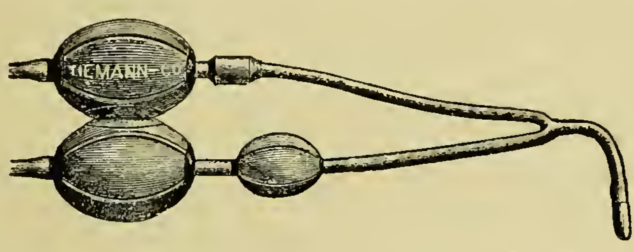


Fig. 42.—Richardson's Double Bellows for Forced Respiration.

Fig. 42. Richardson's Double Bellows consists of two elastic bulbs, to each of which a rubber tube is attached, the two terminating in a single tube. The rubber bulbs are so regulated by valves that air may be forced into the lungs by the compression of one and withdrawn by the compression of the other. When in use, the single terminal tube is introduced into one nostril, the other nostril and the mouth being closed. By alternately compressing first one bulb and then the other, the respiratory current may be artificially established. In actual operation this appliance has not proved successful to any great extent.

of the apex beat, one pole being over the fourth dorsal vertebra. In some instances remarkable results have been obtained from inversion of the patient, and the pulse has been observed to come and go with change in posture. Some cases appear to have been utterly hopeless from the start, but resuscitative measures should be persisted in until it is clear that no possibility of recovery remains.

Mankowski finds, from experiments on animals, that the injection of a 1 per cent preparation of suprarenal extract into the jugular vein stimulates the heart and respiration and prevents the fall of blood pressure from chloroform narcosis. Its preliminary administration before anæsthesia has been advised. Hobday advises the use of hydrocyanic acid as a better and quicker respiratory stimulant than strychnia. In animals, 1 mm. of Scheele's acid was dropped on the back of the tongue for every 7 or 8 pounds of body-weight of the animal. Bernard considers hydrocyanic acid a dangerous antidote for chloroform.

CHAPTER XI.

ETHYL BROMIDE.

Ethyl bromide, hydrobromic ether, bromhydric ether, is a colorless, volatile liquid with a fragrant odor and a hot, saccharine taste, and a bitter after-taste. It was discovered by Serullus, in 1827. Its sp. gr. is 1.420, and its boiling point is 104° F. It decomposes rapidly on exposure to light and air, and when ignited burns with a fine, green, smokeless flame with the separation of bromine vapor. It is sparingly soluble in water, and freely so in strong alcohol and in ether. It should evaporate from the hand quickly and absolutely without residue, and with a distinct feeling of cold; when washed with water the washings should be neutral, and without change with the addition of silver nitrate; no discoloration should be caused by the addition of concentrated sulphuric acid.

Ethyl bromide was introduced as an anæsthetic by Nunneley, of Leeds, in 1865. It was extensively used by Dr. Lewis, of Philadelphia, in 1879-80. A death in his practice, and one in that of Dr. Marion Sims, of New York, together with arguments tending to prove that the drug paralyzed the heart, caused it to fall into disuse. According to Schleich ethyl bromide would be an ideal anæsthetic if the advantage of boiling-point were sufficient to offset the danger of the bromine.

The physiological effects of ethyl bromide are rapidly acquired and are not specially unpleasant. The odor is not disagreeable nor is the vapor particularly irritating to the air passages. The stage of excitement is very short or absent altogether, and muscular rigidity is not marked or is absent. The face is usually flushed, the ears quite red, and the conjunctivæ injected. The pupils are more or less dilated. The heart action is rapid, and the pulse increased in force. The respiration is quicker than normal and becomes slightly snoring or stertorous. Tendency to irregularity of breathing or arrest of breathing has not been noticed. Embarrassed respiration may occur from free secretion of mucus. Nausea and vomiting is rare, but appears more often in women than in men.

Properly administered, insensibility may be induced in about five minutes (Levis); 66 seconds (Chisholm).

The duration of anæsthesia is rather brief,—46 seconds (Silk) and the recovery is rapid, so much so as to constitute in some instances, an objection. If the administration is continued beyond two or three minutes, or if the inhalation is repeated there is more likelihood of after effects.

After effects are usually absent if the administration has not been prolonged. Headache, nausea, or even vomiting may follow. Depression and faintness have occurred. Hysterical manifestations have been noted.

The dangers of the administration of ethyl bromide are probably not great if a pure drug is employed and the administration properly carried on. Wood, of Philadelphia, regarded ethyl bromide as a cardiac depressant. Trumbull and Gowers, of Philadelphia, regarded it as safe and prompt.

The death rate is unknown, and how far the drug was to blame in those deaths that have occurred under its use is questionable.

The administration of bromide of ethyl should not be undertaken for lengthy operations. It is adapted only for dental surgery or general surgical proceedings of not over three minutes' duration, though operations lasting for considerable time have been performed under its use. Chisholm thought it unequaled for ophthalmic surgery.

The inhalation should be conducted much as with ether, the drug being promptly given without much air at first. From one to one and a half drachms is the quantity usually necessary to induce unconsciousness. The inhalation may be conducted with a towel or napkin, as with chloroform, or any ether inhaler may be used. Herz, a dentist of Vienna, used a simple mask such as the Skinner, with cotton inserted upon which he poured at first about half an ounce of the drug, using more later if desirable.

If soft snoring, or insensitive corneæ do not promptly appear, the pulse and respiration should be looked to carefully. When complete unconsciousness is produced the inhalation must be interrupted. The inhalation may be repeated, but as before

stated, unpleasant effects are more likely to follow repeated inhalations.

Ethyl bromide is very portable, requires no apparatus for the administration, is rapid in effect, its inhalation produces no specially disagreeable symptoms, and the recovery is rapid. On the other hand it decomposes readily, is not suitable for lengthy operations, is not as safe as nitrous oxide, and after effects are liable to occur. Kempter urges a more extensive use of ethyl bromide in minor surgery. He says German statistics show but 16 deaths in 60,000 administrations. A fresh preparation is necessary. He pours from 1 to 3 drachms into a cone which is not removed until anæsthesia is induced. No air is admitted. Anæsthesia lasts from 1 to 2 minutes.

Fowler favors ethyl bromide preliminary to ether. The cone need not be changed. Krusen thinks ethyl bromide an ideal anæsthetic in obstetric and gynæcological practice.

ETHYL CHLORIDE.

Ethyl chloride is a colorless, mobile liquid with a pleasant odor. It has a formula of $C_2 H_5 Cl$. It boils at 12.5° C. (Regnault), and is quite soluble in alcohol. So dissolved it may be kept in tightly corked bottles from which ethyl chloride may be obtained by gently heating (*vide* P. 197).

The anæsthetic properties of ethyl chloride were said to have been recognized by Flourens and others. It was recommended by Richardson in 1867 as a good anæsthetic. Within the last three years it has been used by German, French and American observers for surgical operations of short duration, and for dental purposes. Tuttle, of New York, has, of late, used ethyl chloride in 230 cases of short-term anæsthesia. He has never observed any serious symptoms. It may be used with an ordinary chloroform inhaler. It is convenient and safe for operations lasting not over ten minutes. General muscular relaxation is not as complete as under ether. Nausea is sometimes present but soon ceases. Alcoholic subjects appear to bear ethyl chloride very well.

Lothiessen, of Innsbruck, used ethyl chloride in 1896, producing complete anæsthesia in one minute. The drug was sprinkled on an Esmarch mask. The patient recovered in a few seconds. He has since used it many times with no unto-

ward effects. From 8 to 10 grammes were necessary for short operations.

An inhaler devised by Bruer, and resembling Clover's inhaler, is said to be the best for the administration of ethyl chloride. About 3 to 5 grammes of the drug are sprinkled on the gauze, the patient is told to breathe quietly, and the face-piece is pressed closely to the mouth and nose so as to be air-tight. The above quantity of the drug will be sufficient for about 3-4 minutes, and if longer narcosis is desired more must be added. The drug may be sprayed on the gauze of an inhaler from a tube of ethyl chloride.

Anæsthesia is induced in about a minute and a half. Excitement is generally absent. Corneal and pupillary reflexes are usually preserved. The eye-balls may be movable, and the eyes appear to notice. The pulse rate may be slower, but otherwise the pulse is not affected. The conclusions of König as to the influence of ethyl chloride on blood pressure are as follows: With a proper amount of air there is no diminution of blood pressure, though narcosis may be complete; in some instances there may be a fall of blood pressure from vagus irritation. Section of the vagi raises the blood pressure; when a proper amount of air is not allowed lethal depression of the blood pressure and respiratory paralysis follow. The respiration is more rapid than normal. Cyanosis is rare. The muscular system is not always relaxed. The duration of anæsthesia may be prolonged by using more of the drug from time to time. Recovery is rapid, and after effects not important. Vomiting has occurred in a few instances.

Ethyl chloride is not suitable for lengthy operations, but appears to be quite available for dental and short-term surgical operations.

Lotheissen states (1900) that statistics show that ethyl chloride stands next to chloroform as regards mortality. Mackie recommends ethyl chloride in nasal surgery. Ware, from a considerable experience, concludes that ethyl chloride is relatively safe; its danger point is not as readily or suddenly reached as is that of chloroform; it does not show the remote dangers of ether, and asphyxia, when it occurs, is easily relieved by artificial respiration.

BICHLORIDE OF METHYLENE.

Methylene, methyl dichloride, or bichloride of methylene ($CH_2\ Cl_2$), is one of the marsh gas (CH_4—methane) series. The chloride of methyl ($CH_3\ Cl$) has been used for local anæsthesia by freezing. It has been claimed that bichloride of methylene is simply a mixture of chloroform and methylic alcohol.

Bichloride of methylene was introduced as an anæsthetic by Richardson in 1867. It is difficult to preserve, and expensive to obtain pure. It has a low boiling point. According to Richardson anæsthesia is reached more quickly than with chloroform, is more prolonged, recovery is more rapid, and there are no after effects. Spencer Wells expressed himself very favorably towards the drug as having fewer drawbacks than any other known anæsthetic. Buxton thought its dangers differed only in degree from those of chloroform. H. M. Lyman says the effects are similar to those of chloroform; that four cubic centimeters produce insensibility. There are no unpleasant effects with returning consciousness, and vomiting is less frequent than after chloroform.

The dangers of the administration of bichloride of methylene are not accurately known. It is probably not less, and by some is considered more, dangerous than chloroform.

Andrews, of Chicago (1877), gave one death in 7,000 inhalations; Coles, of Virginia, gave two deaths in 10,000 inhalations.

Wells used the Junker inhaler for administering methylene. Strahan, of New York, has used a napkin for the administration. In one case the anæsthesia was continued for 45 minutes, and one and a half ounces of the drug were consumed.

ETHIDENE DICHLORIDE.

Ethidene dichloride, dichlorethene, monochlorethyl-chloride, chlorinated chloride of ethyl ($CH_3\ CH\ Cl_2$) was first prepared by Regnault by the action of chlorine on ethyl chloride. It has an ethereal odor, and a sweet, biting taste. Sp. gr. 1.2. Boils at 135° to 150° F. It is soluble in alcohol and in ether, and is insoluble in water. It is metameric with Dutch liquid or ethylene dichloride.

As an anæsthetic, dichloride of ethidene was first used by Snow. Binz considered it preferable to chloroform. Anæsthesia is produced somewhat quicker than with chloroform, while

the amount of drug consumed is somewhat greater. The pulse and respiration are less changed than with chloroform, and slow pulse and rapid breathing are generally absent. Excitement is generally not marked, though struggling may at times be present. Clover recorded 1,877 cases of the inhalation of ethidene. 287 of which were for major operations. He usually anæsthetized with nitrous oxide by the Clover inhaler for gas and ether, ethidene being gradually added when the patient was partly under. Struggling was rare, though there was some twitching. Stertor and dilated pupils appeared quickly. Air was then admitted as required.

The Junker inhaler has been used for the administration, and it has also been conducted with a towel or piece of lint.

The dangers of the administration of ethidene are not fully understood. Some four or five deaths have been reported under its use, but in how far they were due to the anæsthetic itself is doubtful. Ringer thought that ethidene and chloroform were equally poisonous to the heart. The drug is probably more stimulating than chloroform, but less so than ether, and has generally been regarded as not more safe than chloroform and decidedly less so than ether.

The after effects of ethidene are usually not marked. Vomiting may occur, but ceases sooner than after chloroform. Nausea and headache may occur (Sauer). The recovery from ethidene is usually prompt and satisfactory.

AMYLENE.

Amylene, pentylene, pentene, (C_5-H_{10}) is a colorless, thin, volatile liquid with a pungent, unpleasant odor, and little taste. It was discovered by Balard in 1844, and was first used by Snow for anæsthetic purposes. It is a rather indefinite compound, isomeric with several substances. Its sp. gr., as used by Snow, was .659 at 56° F. The boiling point varies from 30° to 62° C. (Duroy). Pure amylene has a boiling point of 38° C. (Duroy). "Pental," is a name applied to a pure form of amylene introduced by Mering, and used by German dental surgeons.

Amylene is not very soluble in the blood and patients recover very rapidly from its effects. The anæsthesia is therefore transient. Dilute vapor does not induce anæsthesia. Lid-reflex is not always abolished. Muscular spasm may or may

not be present. The pulse and respiration are increased in frequency and force. The pupils may be unchanged. The face is flushed, and there is perspiration. Snow used from 3 to 4 drachms to anæsthetize, with about a 15 per cent. vapor.

The dangers appear to be much the same as with chloroform. Two fatal cases in Snow's practice, together with the transient nature of the anæsthesia discouraged its use, which has never become general. The after effects are not marked. Nausea and vomiting may exceptionally occur.

PENTAL.

Pental has been used in Germany in dental practice. Some kind of inhaler on the order of the Clover inhaler is used. Two or three drachms of pental are placed in the reservoir, the bag is attached, and the patient's expirations are allowed to partly fill the bag. The indicator is first opened as the face-piece is applied. The patient breathes to-and-fro for about 40 seconds, the indicator being gradually pushed more and more open. The inhalation period lasts about 40 seconds, during which there is flushed face, dilated pupils, open eyes, fixed eye-balls, no conjunctival reflex, quick pulse, rapid, labored breathing, slight cyanosis, and may be marked muscular contractions. The available period of anæsthesia lasts about one minute. The face-piece is removed after about 40 seconds, and the operation begun.

Several fatalities have occurred under pental, and other cases with dangerous symptoms have been reported. After effects are usually absent. It is difficult to see what advantages amylene or pental possess over nitrous oxide or chloroform.

Among the other agents which have from time to time been used for producing anæsthesia, but which have various disadvantages, and which are inferior to those already considered, may be mentioned nitrogen, methyl oxide, ethylene (olefiant gas), ethyl nitrate, amyl chloride, amyl hydride, tetra-chloride of methane, aldehyde, bisulphuret of carbon, benzene, turpentine, etc.

SPINAL ANÆSTHESIA.

Spinal anæsthesia, medullar cocainization, the induction of a more or less general anæsthesia by the injection of cocaine into the sub-arachnoid space in the lumbar region, is not, strictly

speaking, a method of general anæsthesia, and yet the anæsthetic area thus produced is sufficiently large to allow of the performance of many operations that could otherwise be done only under one of the general anæsthetics. Therefore this method appears to be entitled to a place in this section.

This method of producing anæsthesia is generally spoken of as Bier's method, or Quincke's method. It properly should be attributed to Corning, of New York (Spinal Anæsthesia and Local Medication of the Cord, *New York Medical Journal*, October 31, 1885). Its introduction as a means of anæsthesia is chiefly owing to Bier and Quincke.

Effects. Acording to Tuffier the effects are as follows: Analgesia appears in from four to ten minutes, quickest in young subjects. It lasts from 30 to 50 minutes with doses of from 5 to 15 milligrammes; with doses of from 15 to 25 milligrammes it lasts from one hour to one hour and forty minutes. The anæsthesia is accompanied by prickling in the toes and calves, and numbness of the lower limbs. Analgesia begins in the extremities and progressively ascends involving the umbilical region last. It disappears in reverse order to its appearance.

According to Crile injections into the subarachnoid space cause displacement similar to that of fluid in a capillary tube. The injection of a cocain solution colored with methylene blue into the lumbar region stained the entire cord and under surface of the brain within thirty seconds, and all the localized functions of the cord and medulla were rapidly anæsthetized. There was marked fall in blood pressure and interference with respiration within a few seconds. Position affected the rapidity of the occurrence of these manifestations little if at all, and the operator has little if any control over the extent of anæsthesia produced by subarachnoid injection.

The general symptoms observed during analgesic and postanalgesic periods are: Sweating, some dilatation of the pupils, nausea, trembling, headache, vomiting, shivering, and tachycardia. They may be absent with small doses.

Eucaine b, alpha eucaine, and tropacocaine have been used but do not appear to have special advantages. Kopfstein reports fever, headache, and collapse after using alpha eucain.

After effects. These are less marked and unpleasant than

after general anæsthesia. Nausea and vomiting occurs in from 20 to 40 per cent. of the cases. Headache, pain in the legs. delirium, paralysis of the sphincters, and collapse may occur.

Complications. Late complications are absent as a rule.

Failure to produce anæsthesia occurs in some cases, and cannot always be attributed to faulty technique. It may be necessary to give a general anæsthetic.

Contraindications. Conditions which render general anæsthesia dangerous also bear the same relation to spinal anæsthesia. It should not be employed in children under 12 years. It should not be used when absolute muscular relaxation is necessary. It is contraindicated in most mental conditions. Some regard spinal anæsthesia as safer in kidney disease than general

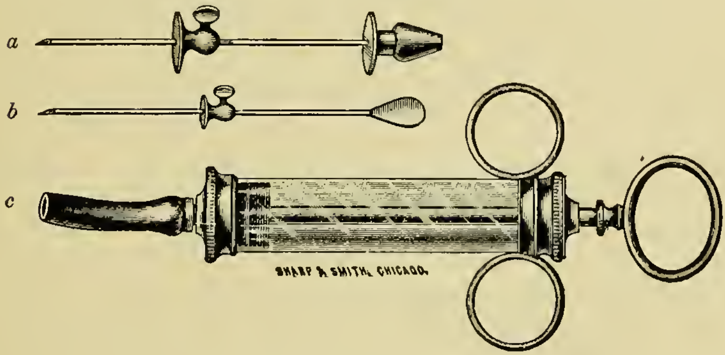


Fig. 43.—Corning's Original Needles and Syringe.

anæsthesia, but this is not yet proven. It should not be used for operations lasting over one hour, or for those in which complications are likely to arise and prolong the operation beyond this period.

Mortality. The mortality of spinal anæsthesia is not known. Such deaths as have occurred cannot be attributed solely to the method of anæsthesia. Statistics, up to date, are inconclusive. It should not be used when local anæsthesia is possible.

The solution and dose. The solution used should be weak (a one or two per cent. solution). It should be freshly prepared, sterilized by heating several times in a water bath at a temperature not exceeding 60° C. The majority of operators use a two per cent solution of cocaine as employed by Tuffier.

A quantity not to exceed 15 mgm. is injected. This quantity may be exceeded but is likely to be followed by after effects.

According to Matas the solution should be made as follows: "Five tablets each containing 1-5 grain of cocaine hydrochlorate, 1-40 grain of morphine hydrochlorate, 1-5 grain of sodium chloride are dropped into 100 minims of hot distilled water and dissolved. The solution is again sterilized by the fractional method. Twenty minims of this solution represent one-fifth of a grain of cocaine, one-fortieth of a grain of morphine, and

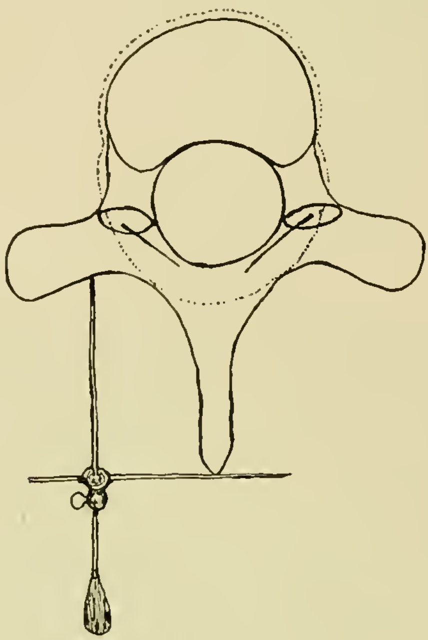


Fig. 44.—Diagram of Vertebra.

one-fifth of a grain of sodium chloride. The syringe, which contains 30 minims, is filled with the solution and 22 minims are injected. The excess of 2 minims is allowed for waste. The solution should always be used warm, about 90° to 100° F." He claims that this method is very satisfactory.

Technique. Corning's original method differed from that used by later authorities. He used for measurement a fine needle, three inches long, provided with a handle and a sliding nut (Fig 43-b). This needle was introduced half an inch to

one side of the spinous process of the tenth dorsal vertebra until the bone was reached. The nut was then slid down until it rested on the spine and was fastened by the screw. Fig. 44 shows this needle and gives the exact distance between the skin and the cord. A hollow needle (Fig. 43-a), with a sliding nut fixed at the proper distance, and attached to a syringe (Fig. 43-c) filled with cocaine solution, is thrust between the spinous processes of the tenth and eleventh dorsal vertebræ and the solution injected. Later Corning discarded the needle used for measurement and employed a delicate trocar containing a fine needle (Fig. 45), and used the sitting position instead of the lateral for the operation. The needle is introduced slowly

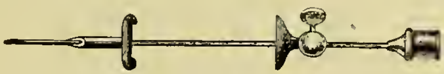


Fig. 45.—Corning's Needle.

until a few drops of spinal fluid escapes, when the injection is made.

Bier and Quincke used the lateral position, and a thin hollow needle with a stopper. After the appearance of the cerebrospinal fluid the solution is introduced with a Pravaz syringe. The technique is as follows:

Place the patient on his side, round his back by flexing the legs on the thighs and the thighs on the abdomen and place a cushion underneath the flank. This will widen the spaces between the spinous processes of the vertebræ. The lumbar region is cleansed. The posterior, inferior iliac spines are located and joined by a line which passes the level of the fifth lumbar vertebra. Below this line will be found the sacrolumbar fossa, and from this point count the lumbar spinous processes until the third or fourth lumbar interspace (the point of election) is reached. This point is marked with iodine, and rendered anæsthetic by ethyl chloride or some other local anæsthetic. The spinous process corresponding to the space elected (third or fourth lumbar) is located, and keeping the finger on the process, the needle, which should be strong and three or four inches long, is inserted one-half cm. to the outer side (right or left) of the median line. The needle is held by the thumb and index finger of the right hand and gently pushed

from behind forward, from below upward, and from without inward, the obliquity of the needle inward and upward being slight. The needle is most likely to be arrested by the superior lamina of the space it is traversing, if so it should be slightly withdrawn and its direction changed. The external orifice of the needle must be watched, for as soon as the needle traverses the inter-laminar space it enters the sub-arachnoid space, and the spinal fluid will escape. Cocaine must not be injected unless this escape of spinal fluid takes place. When 8 to 10 drops of fluid have escaped the injection is made very

Fig. 46.—Sitting Position.

slowly. When the needle is withdrawn the point of injection is sealed with collodion.

The technique of lumbar puncture may, at times, be difficult In obese or muscular subjects palpation of the spinous processes of the lumbar vertebræ is difficult. The sitting position is better than the lateral. The needle should be introduced slowly, and the appearance of the spinal fluid alone should be regarded as evidence that the needle has penetrated the canal. Very little spinal fluid should be allowed to escape. About one minute should be consumed in injecting the solution. The

needle should be left in place after the injection for five or ten minutes. Repeated injections have been made, but are considered dangerous. Surgical cleanliness should be carefully observed. The skin may be previously anæsthetized by the Schleich infiltration method, or by the ethyl-chloride spray, but this is considered unnecessary by most operators. The needles and syringes should be kept exclusively for this purpose and should be carefully sterilized and tested before using.

The location of the puncture. The inter-vertebral space between the third and fourth, or fourth and fifth, lumbar verte-

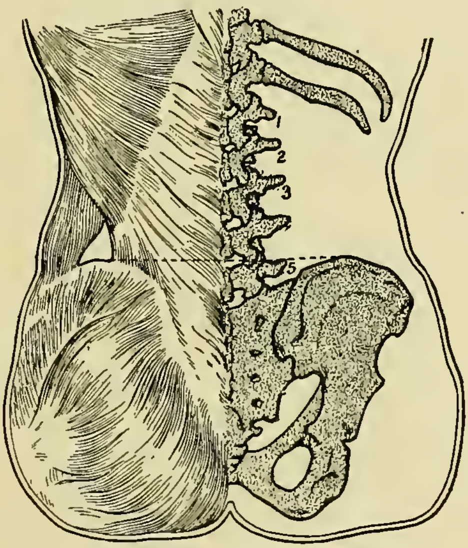


Fig. 47.—Iliac Crests.

bræ is usually selected. Chipault used the space between the fifth lumbar vertebra and the sacrum, which is also preferred by Rodman. Corning first used the space between the eleventh and twelfth dorsal vertebræ, but later preferred that between the fourth and fifth lumbar vertebræ. Tait and Cagliari, of San Francisco, have injected as high as the sixth cervical space, but most authorities condemn injections higher than the second lumbar vertebra.

Position and method. The lateral position and technique

already described may be used. Matas recommends the method employed by Tuffier, and first used by Quincke.

The patient is seated on a table with his back to the operator (Fig. 46). His hands resting on his thighs support his trunk. The trunk is held nearly upright with the spine as straight as possible. The highest points of the iliac crests posteriorly are now identified (Fig. 47), and a horizontal line

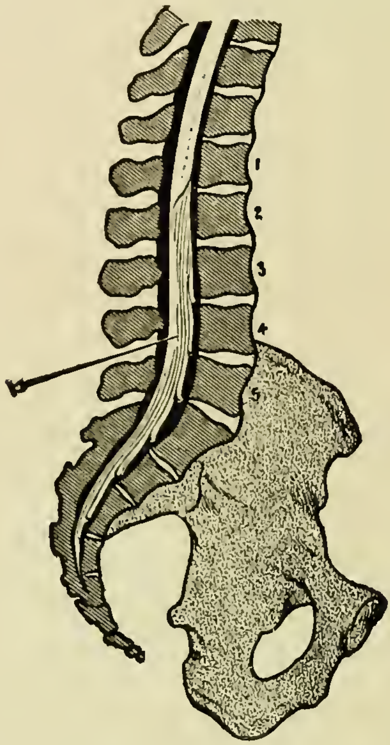


Fig. 48.—Needle Entering Opposite Fourth Spine.

connecting these points is drawn across the spine. The tip of the fourth lumbar spine touches this line. The canula is entered at a point just below and to the outer side of the junction of this line with the fourth spine (Fig. 48). The skin at this point and for a quarter of an inch to the right of the median line may be infiltrated with a few drops of Schleich's cocaine solution No. 1 or No. 2. A Pravaz syringe, as used by Tuf-

fier, may be employed (Fig. 49), with a platinum needle 8 cm. long, and a lumen of 6 mm. The various methods of inserting the needle are shown in Fig. 50.

Guinard claims to have succeeded in suppressing all after effects of medullar cocainization by using a solution of cocaine in the rachidian liquid of the patient, 60 to 80 drops of this liquid are collected in a sterilized bottle, and 6 or 7 drops of a concentrated solution of cocaine (about 1 centigramme to 2 drops of water) are added and the whole slowly injected.

The following account of the method of A. W. Morton, of San Francisco, is taken from his article on "The Sub-Arachnoid Injection of Cocaine for Operations on the Upper Part of the

Fig. 40—Tuffler's Needle and Syringe.

Body," read at the fifty-third annual meeting of the American Medical Association, (Jour. Am. Med. Assn.)

"Chemically pure cocain hydrochlorate is sterilized by exposing the crystals to dry heat 300 F. for fifteen minutes, then inclose in sterile tubes, or sealed envelopes, in proper doses until time for use. The dose varies from 0.3, 0.4 or 0.5 of a grain, depending on the locality, whether in the lower extremities, trunk, or head. This is the maximum dose for a strong person; young or old persons will take a smaller dose.

"I use the Lures syringe, which has a glass piston, and graduated barrel, and is readily sterilized, and always in working order. The needle is made of steel wire tubing No. 19 gauge, and three inches long; the bevel is short, with the concave portion of it dulled, to prevent cutting plug of skin and obstructing needle. The needle is kept in a saturated solution of carbonate of sodium to prevent rusting.

"The patient is placed in the reclining position on either side, with body curved forward, to separate the spinous processes; the spinous process of the fourth lumbar vertebra is located by being on an imaginary line connecting the crest of the ilia.

The space just between the third or fourth lumbar vertebra is frozen with ethyl chlorid, after being thoroughly cleansed. The needle is introduced just beneath the spine in the median line, with the point of it directed upward, and introduced until it meets with diminished resistance, or fluid passes. Should the needle be obstructed, it can be opened by having the patient cough, using stylet, or making suction with syringe attached, at which time a drop of cerebro-spinal fluid will pass. Then place the finger over the end of the needle and connect the

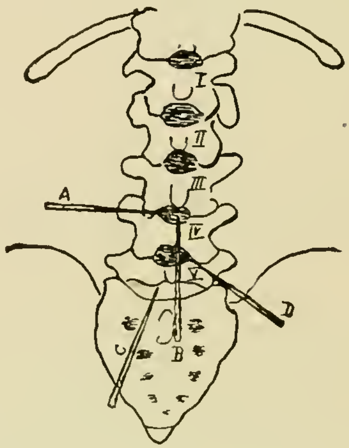


Fig. 50.—Method of Puncture for Spinal Drainage.

Fig. 50. Methods of puncture for spinal drainage: A. Quincke's method; B. Warfan's; C. Chipault's; D. Tuffier's—after Matas, modified from Chipault.

syringe, which has 0.3 of a grain of cocain in it, with piston closed, and gradually withdraw the piston, until the syringe is half filled with cerebro-spinal fluid, which readily dissolves the cocain; then gradually return the solution into the space by pressing the piston.

"Should the analgesia be desired in the upper extremities, introduce the needle in the third space, and use the same method as above, except the dose should be 0.4 to 0.5 of a grain of cocain, and introduce as rapidly as the piston of the syringe can be pressed, then withdraw the needle and seal with collodion.

"The analgesia will be complete for operations in the lower

extremities in from three to five minutes, and for operations in the upper part of the body, in from fifteen to twenty-five minutes; the analgesia lasts from one to three hours, and I have seen it last five hours.

"I have seldom found it necessary to repeat the injection for prolonged operations, or incomplete analgesia, but should it be necessary, I see no objection to repeating the dose.

"The action of such a small amount of cocain to produce profound analgesia has caused considerable discussion. I am of the opinion that it acts locally by coming directly in contact with the roots of the nerves, and it has a special affinity on the fibers which carry the sensation of pain.

"The patient will occasionally complain of cramps in the limbs, or of a warm sensation over the entire body, rapid pulse, perspiring, nausea, vomiting, involuntary evacution of the bowels during the early part of the analgesia, headache and chills after it. The vomiting occurs in about every eighth case, and usually comes on in about ten or fifteen minutes after the injection, and lasts only a few minutes; it is very seldom that it occurs after the operation. We often have a rapid pulse during the operation, especially if the patient is excited or nauseated. The rapid pulse is generally associated with the nausea, but there is sometimes a condition of depression which is evidently a form of shock due to some disturbance of the centers brought about by the injection, but I have never seen it very alarming, except in one case where I withdrew considerable cerebro-spinal fluid for analysis. The much dreaded headache will seldom if ever occur if the cocain is dissolved in the fluid, and none of the cerebro-spinal fluid wasted. In dissolving the cocain in the cerebro-spinal fluid, we not only disturb the parts less by placing a less amount of foreign element in the canal, but the fluid is kept at the same temperature, and is not in any way disturbed by diminishing or increasing the amount of fluid in the cerebro-spinal space. If this is carried out you will seldom find headache. I have observed nine chills during the first few days after the operation; in some of them I was unable to find any cause for the disturbance, except it be this method of analgesia; there was no serious condition as a result."

Ravaut and Aubourg have practised a second lumbar puncture

some hours after the operation in order to relieve the after symptoms (headache, vertigo, and vomiting) by relieving the patient of a certain amount of cocaine which chemical examination has proved to be free in the cerebro-spinal fluid, and to relieve the tension of the fluid. The more severe the case the greater the tension, and the more turbid the fluid. In mild cases only a small quantity is withdrawn. In severe cases as much as 20 cubic centimeters was withdrawn. Examination of the fluid showed the turbidity to be proportionate to the abundance of polynuclear leucocytes. Fibrin was present in severe cases of headache. The intensity of the latter was in proportion to the abundance of polynuclear leucocytes and the amount of fibrin. On the third or fourth day the polynuclear leucocytes became replaced by lymphocytes and mononuclear leuocytes, and in from eight to twenty days the fluid became normal. The cocaine is the direct cause of this leucocytic action, and its action on the membranes of the cord is compared to that of a toxin.

Spinal cocainization is attended with considerable danger. A number of deaths have occurred under its use. Leguen reports two deaths when less than 2 centigrammes of cocaine was injected. There is open opposition to its employment from several eminent men, and the limitations of its usefulness are not yet settled.

CHAPTER XII.

MIXTURES FOR ANÆSTHESIA.

Mixtures of alcohol, chloroform and ether, chloroform and ether, and chloroform and alcohol have been more or less extensively employed with the object of obtaining anæsthesia with a less concentrated vapor, and of obviating depression of the circulation. The addition of ether to chloroform, or to chloroform and alcohol, produces a better and more uniform circulation during anæsthesia than is the case with chloroform alone. The difference in the boiling point, and in the volatility of the constituents of these mixtures renders it difficult to control the proportion of the various vapors inhaled. Ellis devised an apparatus in which the ingredients were separate and the vapors were mixed in the desired proportions during the administration. This apparatus was too complicated for general use. The difficulty is overcome to some extent by using such proportion of the different ingredients as will evaporate in the same time at the same temperature. Or, by using only small quantities of the agent at a time, and as frequently repeating the dose as the previous one evaporates.

THE A. C. E. MIXTURE.

Of the various mixtures used for anæsthetic purposes the A. C. E. mixture, consisting of 1 part of alcohol, 2 parts of chloroform, and 3 parts of ether, has been the most extensively used. It was originally suggested by Harley. According to Martindale, by using alcohol of a sp. gr. of .795, chloroform of a sp. gr. of 1.497, and ether of a sp. gr. of .720, uniform volatility will be secured. The mixture should be freshly prepared, and kept in well-corked bottles.

When inhaled the odor of the mixture is not unpleasant. The effects are more similar to those of chloroform than of ether, though partaking of the peculiarities of both. Thus there is deeper and more audible respiration than with chloroform, while concentrated vapor will produce swallowing, coughing, holding the breath more readily than chloroform. There is more saliva than with chloroform, and less than under ether.

The administration should be conducted with an Esmarch or

an open cone inhaler. Plenty of air must be allowed, and small quantities of the mixture used at a time. If attempts at vomiting occur the anæsthetic should be carefully continued. From five to ten minutes should be allowed for the induction of anæsthesia. Regular, stertorous breathing, no lid-reflex, muscular relaxation, fixed eyeballs, and moderate contraction of the pupils indicate a proper degree of anæsthesia. According to Hewitt, a dilated pupil with distinct lid-reflex allows of more anæsthetic if desirable, but a dilated pupil with insensitive corneæ indicates withdrawal until the pupil contracts or lid-reflex appears. High-pitched, crowing breathing as a rule indicates withdrawal and friction of the lips. Quiet breathing, tendency to rigidity, swallowing, marked contraction of the pupils, indicate too light anæsthesia.

The A. C. E. mixture is regarded by many anæsthetists as one of the best agents for routine use. It is well adapted for old or fat people, emphysematous subjects, and those suffering from bronchitis, asthma, pleurisy, chronic diseases of the lungs, and in cardiopathic patients. It is recommended by Hewitt for cases of mitral stenosis. It is advantageous for cases of abdominal disease, and is well adapted for use with children.

The after-effects of the A. C. E. mixture are, as a rule, unimportant. Vomiting may occur. The dangers of its administration are similar to those of chloroform, although not nearly so great. A number of deaths have occurred under its use, but they cannot all be attributed entirely to the agent. Kemp thinks that the A. C. E. mixture exhibits the effects of chloroform on the heart, and of ether on the kidneys, and sees no good reason for employing the mixture.

BILLROTH'S MIXTURE.

This mixture consists of 1 part of alcohol, 3 parts of chloroform, and 1 part of ether. It has been used considerably in Germany. Its administration and effects do not differ materially from those of chloroform, except that the circulation is better, and there rarely is any after vomiting.

CHLOROFORM AND ETHER.

Various proportions of chloroform and ether have been used. They should never be administered by closed or bag inhalers. Small and frequently repeated doses are best.

Two parts of chloroform and three of ether.—This is the

same as the A. C. E. mixture, without the alcohol. It is recommended by Hewitt, who says there is less excitement and more satisfactory recovery than with the A. C. E. mixture. He thinks that if small quantities be used repeatedly, and with a proper inhaler, that no difficulty will arise with this mixture or with the A. C. E. mixture. The administration is governed in all respects by the rules which apply to the A. C. E. mixture.

Two parts of chloroform and one of ether.—This mixture is recommended by Fuster. It should be freshly prepared. No special inhaler is necessary. A wire frame covered with flannel may be used. When the patient is breathing quietly, 4 or 5 drops are poured on the inhaler. When this has evaporated 6 or 8 more are poured on at the moment of inspiration. Two or three such doses are given during the first minute, and if well taken, three or four are given during the second minute, by which time operation may be begun. If there is any evidence of pain, a few more drops may be given with the next inspiration. Anæsthesia is produced in from two to five minutes, and may be continued for a long time by administering 3 or 4 drops from time to time. Excitement is rare, vomiting unusual, and the circulation well maintained.

One part of chloroform and four parts of ether.—This mixture has been used experimentally mostly. Its effects are very similar to those of ether.

One part of chloroform and three parts of ether.—This mixture, known as the Vienna mixture, has been quite extensively used in some parts of Europe, and is said to be very satisfactory. It has not been much employed in this country.

One part of chloroform and two parts of ether.—This mixture is similar in its effects to the A. C. E. mixture. It has not been much employed.

CHLOROFORM AND ALCOHOL.

Equal parts of chloroform and alcohol have been used by Sansom, and by Snow. Usually, however, a lesser proportion of alcohol has been employed. Vigorous subjects are difficult or impossible to anæsthetize with a large proportion of alcohol. Such mixtures should be administered in the same manner as chloroform.

SCHLEICH'S MIXTURE.

Schleich introduced this mixture in 1898. It consists of chloroform, ether, and petroleum ether, united in such proportions and in accordance with the temperature of the patient, that absorption and elimination will be balanced and no accumulation be possible. A narcotic which evaporates quickly is eliminated quickly. One evaporating slowly is eliminated slowly and becomes dangerous. The lower the boiling point of the agent the more rapid the evaporation, and *vice versa.*

Schleich found that when the boiling point of the agent is higher than the body temperature the amount necessary to secure anæsthesia is less than when the boiling point equals the body temperature, and that the resulting narcosis is deeper. Also that it is possible to mix ethers having different boiling points in various proportions and to obtain a desired boiling point and to regulate it according to the proportion of each used. He recommends three mixtures which may be prepared by the anæsthetist.

Petroleum ether is best for modifying the action of chloroform, diluting the other materials. It does not interfere with the action of the other drugs, and can be given in large doses without causing disturbance. The mixture may be administered as are other agents. Care must be exercised as to the amount used. Thirty gms. of Mixture No. 1 is an average amount for 20 minutes or less. An ordinary towel and paper inhaler will answer. For prolonged operations Mixture No. II. may be used, and a smaller amount will be necessary.

Mixture No. I. consists of chloroform, 45 parts; petroleum ether, 15 parts; sulphuric ether, 180 parts, and boils at 38° C. 100.4° F.).

Mixture No. II. consists of chloroform, 45 parts; petroleum ether, 15 parts; sulphuric ether, 150 parts, and boils at 40° C. (104° F.).

Mixture No. III. consists of chloroform, 30 parts; petroleum ether, 15 parts; sulphuric ether, 80 parts, and boils at 42° C. (107.6° F.). Petroleum ether should boil at 60 to 65° C. (140 to 149° F.).

Rodman used the Schleich mixture in 700 cases in the Mount Sinai Hospital in New York. He concludes that it is more pleasant to inhale than ether, but not as compared with chloroform. It requires from 15 to 20 minutes to induce anæsthesia. A mask is

necessary (Fig. 51), and must be saturated at the beginning, which is apt to burn the face. Excitement is less than with chloroform or ether. Relaxation is more marked than under ether. Reflexes are lost early, especially the conjunctival reflex, which is therefore not a good guide. The pulse is slow, the pupils dilated, and the respiration diminished. Cyanosis is present. If care is not exercised cyanosis increases, breathing is shallow and infrequent, the pulse is rapid and of low tension, and the patient stops breathing. Nausea and vomiting is as frequent afterward as with chloroform or ether, and recovery is not any more rapid. The effect on the lungs and kidneys are as marked as with ether. Rodman claims that Schleich's mixture is inferior to both chloroform and ether.

Garrrigues has employed this method, using solution No. I., and changing to No. II. if anæsthesia is not induced in ten minutes. He concludes that the mixtures are easily taken, may be used in all cases where general anæsthesia is not contraindicated, anæsthesia is induced quickly and maintained with small quantities of the agent, there is little mucus, rarely vomiting, scarcely any tendency to cyanosis, no bad effect on the kidneys, only slight weakness of the heart, not as much danger to respiration as with ether or chloroform, and the mixture is adapted for general usage.

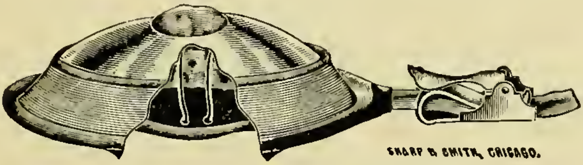


Fig. 51.—Stone's Mask for Schleich's Solution.

Fig. 51. Stone's mask for Schleich's solution is shaped like half an egg shell. Its rim is covered with a circular. rubber cushion adjusting the mask closely to the face. The cushion is inflated by a special tube and stop-cock. The air required for respiration is admitted through a ¾-inch opening in the center of the mask. This pattern is for use in ordinary positions. For Sim's position a special inhaler should be used, one in which the opening is placed on the right side of the mask instead of the center. The inner portion of the mask is supplied with twelve layers of japanned bibulous paper, such as is used by dentists. This is held in place by two spring wires. The latter serve not only to hold the paper in a compact mass, but to prevent them from resting against the nose. The latter feature is necessary as the solution is destructive to the skin when long in contact with it.

CHAPTER XIII.

SEQUENCE OF ANÆSTHETICS.

The following of one anæsthetic agent by another with the same patient at the same administration is a method of anæsthesia which in certain subjects, or for particular operations, may be of considerable advantage. There are a number of these sequential methods of anæsthesia, but certain of them are worthy of special attention.

THE NITROUS OXIDE-ETHER SEQUENCE.

This method was introduced by Clover. It has since found considerable employment in Great Britain and in this country. Brown and Kelly, of Baltimore, report 300 anæsthetizations by this method. The advantages over ether alone are: More rapid induction of anæsthesia, less irritating inhalation, less struggling and excitement, less risk, less ether absorbed, quicker recovery, and fewer after-effects. The fact that both agents demand little air makes the change from one to the other comparatively easy.

The administration may be conducted by a closed inhaler suitable for the administration of both agents, such as the Ormsby, Clover-Hewitt (Fig. 52), Bennett, or Packard inhalers (*vide* p. 112), or the gas may be given by the White dental inhaler, and when unconsciousness is reached ether may be substituted by using an ordinary cone inhaler. The latter method is of advantage in operations about the throat. It has the objection, which Hewitt considers serious when using it in adults, that at the moment of change from gas to ether or during the first inhalations of ether there is an interruption of the breathing which may lead to dangerous spasm of the upper respiratory tract. This is most likely to occur with robust or alcoholic subjects. In children it is not likely to happen, and in them this method is simple and valuable. The Clover-Hewitt inhaler with the Hewitt stop-cock is recommended by Hewitt. The gas bag holds two gallons and is replaced by the ordinary bag of the Clover inhaler when anæsthesia is induced. The ether may be placed in the inhaler after the patient is insensible to its odor, and the transition from gas to ether is gradually made by opening the ether indicator slowly.

The gas bag may be filled in another room, and the patient need not see it. The noise of gas escaping from a cylinder is obviated.

The patient should be fully anæsthetized before ether is admitted or there will be holding of the breath, spasm of the masseters, and struggling or excitement. When stertor is present a breath or two of air may be given.

THE CHLOROFORM-ETHER SEQUENCE.

This method has been considerably employed because the agreeable odor of chloroform adapts it for use as an initial agent, and because no special apparatus is necessary for administration. The objection is raised that a large proportion of chloroform fatalities

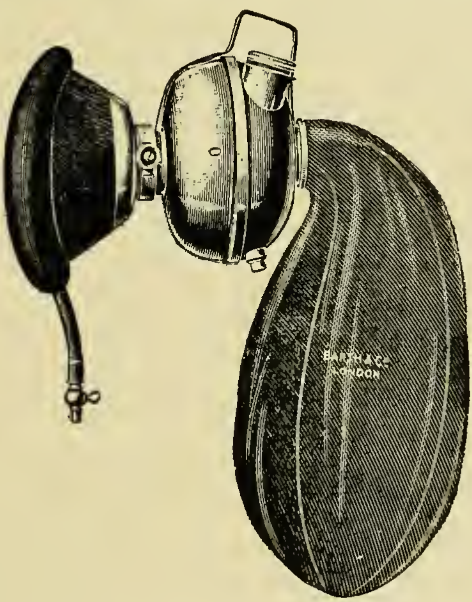


Fig. 52.—Hewitt's Modification of Clover's Inhaler, for N_2O and Ether.

Fig. 52. Hewett's modification of Clover's inhaler was designed for the successive administration of nitrous oxide gas and ether. It has the following modifications from Clover's: (1) The air-way is much larger; (2) The central tube rotates within the fixed reservoir; (3) The face-piece is screwed into the ether reservoir so that the latter cannot be unexpectedly detached from the former; (4) The ether reservoir can be adjusted, with the patient in any position, so that ether may be poured into it without removing the inhaler from the patient's face. There are two separate inner tubes which are made to revolve as one tube by the indicating handle which fits into each.

occur during the initial stage of its administration, and therefore the risk is practically as great as when chloroform is used for the entire period of anæsthesia. It is not necessary, however, to carry the chloroform far enough to entail these dangers, and if care is exercised the risk is much less than with chloroform alone.

The administration of the chloroform should be conducted on an Esmarch mask by the drop method of Prince. As soon as unconsciousness is reached the ether is substituted. Any ether inhaler may be used, or the ether may be given by the drop method on the mask by using a thicker covering for the mask, such as twice the thickness of gauze necessary for chloroform. The change from chloroform to ether can thus be made gradually, and often without any difficulty. Retching, vomiting, struggling, etc., may occur if the change is made too early or if too little anæsthetic be given. Post-anæsthetic retching and vomiting is usually no more frequent or severe than under chloroform alone.

THE A. C. E.-ETHER SEQUENCE.

This method has been largely used and is considered by many to be much superior to the previous method because less liable to cause unpleasant or dangerous symptoms during the induction of anæsthesia. It appears to be a particularly satisfactory method of anæsthesia in persons who are generally regarded as unsatisfactory subjects.

The administration may be conducted in the same manner as with the chloroform-ether sequence. Hewitt recommends for adults, first the mask and drop-bottle, then the Rendel inhaler with half a drachm of the mixture from time to time, and finally the Ormsby inhaler with ether, and in children the mask until respiration is deep and regular, then the Clover inhaler with ether, the indicator being turned to "1." Rowell endorses practically the same method as being the safest routine method in children.

THE ETHER-CHLOROFORM SEQUENCE.

This method is employed when ether is not well borne, or when there is danger in using chloroform as an initial agent. It may also obviate to some extent the danger of complications which attend the continued use of ether in lengthy operations.

In changing from ether to chloroform it is important to make the change under the proper depth of narcosis. Coughing, swal-

lowing, or a moderate sensitiveness of the corneæ indicate a proper condition for the change. Struggling or excitement will be aggravated by the change, and spasm is more liable to result. If too deep narcosis is present the change may result in toxic conditions. The respiratory tract should be free from mucus or blood when the change is made, as the quieter respiration under chloroform may be affected by their presence.

Various other sequences have been adopted with the object of securing the best and safest features pertaining to each agent and applying them to the particular stage of anæsthesia to which they are adapted. Thus we have the nitrous oxide-ether-chloroform sequence, the A. C. E.-ether-chloroform sequence, and the chloroform-ether-chloroform sequence. Properly applied, these changes may be of much utility in special circumstances.

Ethyl bromide-chloroform, A. C. E.-chloroform, ether-A. C. E., nitrous oxide-ethidene dichloride, nitrous oxide and oxygen-ether, are sequences which have been more or less used, but which do not call for special mention, unless it be that the ethyl bromide-chloroform sequence has been warmly advocated by some observers, who emphasize its advantages if care is taken to secure perfectly pure ethyl-bromide. The dangers of the chloroform induction period are done away with and the narcosis is safely and easily continued with chloroform, of which very small quantities are necessary.

CHAPTER XIV.

AFTER THE ADMINISTRATION OF AN ANÆSTHETIC.

The duties of the anæsthetist do not cease with the ending of the administration. He should remain by the patient until consciousness has at least in part returned, or until the patient is asleep, and in case the patient sleeps quietly immediately after the operation, the administrator or some competent person should be on hand when he awakes in order to combat any troublesome conditions that may arise.

Immediately after the operation the patient should be turned on his side. The room should be kept dark and quiet to encourage sleep. The temperature of the room should be about 75° F. Too free ventilation and drafts of air should be avoided. The patient's head should be kept low and he should be covered with a blanket. The stimulation of the circulation from an anæsthetic, especially ether, is followed by more or less depression during recovery, and in weak subjects it is advisable to surround the patient with hot water bottles, which should be wrapped in flannel to prevent injury to the surface of the body.

The rapidity of recovery will depend on the degree of narcosis, the length of the administration, the degree of surgical shock, the nature of the anæsthetic agent, and the nervous character of the subject. When the anæsthetic is withdrawn from a fully anæsthetized subject the first evidence of recovery will be the diminution of stertor, if it is present, and the appearance of quiet breathing. The lid-reflex or swallowing movements, or both, next appear. The pupils grow smaller, or may dilate if the patient is disturbed, or if vomiting is imminent. The eyeballs become mobile. The breathing may be slightly obstructed from swallowing. Expiratory, moaning, or inspiratory noise may be present, and coughing or retching and vomiting may follow. Immediately after the operation the patient should be turned on his side, with the head low and in the median line. If the subject has been in a sitting posture, as for dental or oral surgery, he should be bent forward to allow blood to escape from the mouth, and afterward placed in the lateral, recumbent position. If retching occurs the lower jaw should be pushed well forward.

Faintness, syncope, and weak pulse are generally due to nausea and vomiting. They may, however, be due to the patient's general condition, weak heart, or to shock from the operation. It has been claimed that degenerative changes in the heart muscle may be instituted by the anæsthetic, and that syncope and cardiac failure may occur from this cause in patients whose hearts were previously healthy. This is exceedingly doubtful. It is possible that in some degrees of myocardiac degeneration the anæsthetic may render the heart muscle weaker for some time subsequent to the operation, even if difficulty was not apparent at the time of the operation. Yet, in most cases of chronic muscular disease of the heart, if the dynamic condition is fair at the time of anæsthesia, the after-effects on the circulation will be unimportant.

No food should be allowed for at least five hours after anæsthesia. If the stomach feels badly, a few sips of clear, strong coffee may be given half an hour after the patient is fully conscious.

If the patient feels very prostrated, sipping hot water for a few minutes at a time will act as a good stimulant. If the after-taste of ether is complained of, a small slice of lemon, or some orange juice will relieve it. If the patient is hungry, a little food may be given about four or five hours after the administration. A little meat broth or soup, or some beef extract, such as somatose, Liebig's extract or Armour's extract. I have found the Mosquera liquid extract given quite hot to be very satisfactory. Seltzer and milk may be preferred in some cases.

Vomiting is the most troublesome condition and the hardest to control in some instances. If the patient has been properly prepared for the operation by giving a purgative, and by keeping the stomach empty, vomiting is not as likely to occur as if these precautions are neglected. If the patient is too deeply narcotized, if the anæsthesia is prolonged, if blood or mucus enters the stomach, or if the patient is moved or disturbed during the early period of recovery, there will be greater liability to vomiting. Robust children and women, and bilious, over-fed men, are most liable to vomiting. Patients operated on early in the day are less liable to vomiting than those operated on late in the afternoon. Certain operations, such as abdominal or pelvic operations, are more

liable to be followed by vomiting than are operations about the upper portion of the body.

The kind of anæsthetic and its purity will influence the tendency to vomiting. Nitrous oxide, ethyl chloride, and ethyl bromide are less often followed by vomiting than are other anæsthetics. Ether produces transient vomiting more often than chloroform, but persistent vomiting is more frequent after chloroform.

Many remedies have been recommended for the treatment of vomiting, but it is not always possible to tell what will be efficacious. Ochsner recommends a napkin wet with vinegar laid over the nostrils, an ice bag over the phrenic nerve, sips of hot water every 15 minutes, occasional sips of strong coffee, small pieces of ice in the mouth, and, in persistent cases, hot enemata of normal salt solution. Hunter Robb advises one or two teaspoonfuls of toast water every 20 minutes by mouth for 6 to 12 hours. The head should be kept low, on level with body or only slightly elevated. Vomiting usually stops in from 18 to 20 hours. If it continues after the third day, and if the fluid is expelled without effort, the vomiting is likely due to peritonitis. It may be relieved by two or three drachms of very hot water containing ten grains of bicarbonate of soda, repeated every hour or two. Light mustard plaster may be placed over the epigastrium. It may be necessary to wash out the stomach. The vomiting from peritonitis is hard to control. It is made worse by the administration of drugs. Treatment of the accompanying constipation and tympany may relieve the vomiting. It may be necessary to inject morphine over the epigastrium to relieve retching.

Bonney divides the vomiting after pelvic operations into irritative, neurotic, obstructive, and peritonitic. Irritative vomiting is due to gastritis from the anæsthetic. No food should be given by the mouth. Nutrient enemata may be given. If the vomiting is not severe, peptonized milk and lime water may be given, or one dram of bicarbonate of soda in three ounces of hot water one-half hour before food, or bismuth and bicarbonate of soda every three hours may be taken. For bilious vomiting, one dram doses of bicarbonate of soda should be used. For neurotic vomiting, a little brandy in the food, and moral suasion, with mustard to the epigastrium. Soap and water enemata are very useful in all forms of vomiting.

In some cases the procedure used by Joos for vomiting during anæsthesia may be beneficial—compression of the phrenic nerve and the vagus on the left side immediately above the sternal end of the clavicle, by the thumb, the hand laying flat on the thorax parallel with the clavicle.

Blumfeld advises lavage of the stomach with plain water for after-vomiting, and Lenevitch advises the same proceeding with lukewarm alkaline solutions. In neurotic subjects an enema of 20 to 25 grains of potassium bromide in three or four ounces of water may be useful. For persistent vomiting we may try one minim doses of tincture of iodine every two hours, or one-third of a grain of zinc oxide three or four times daily, or one-two-hundredth of a grain of bicarbonate of potash on an empty stomach, or one drachm every 15 minutes of a mixture of 4 drops of creosote to 2 ounces of lime-water, or teaspoonful doses every hour of 2 ounces of lime-water containing 1 grain of carbolic acid, or one-half grain doses of menthol in liquid vaseline, or one-eighth grain doses of cocaine, repeated as necessary. Persistent nausea may often be relieved by small amounts of champagne, or by 1 or 2 grain doses of oxalate of cerium.

Bronchial and pulmonary symptoms may arise from the presence of foreign substances in the respiratory tract. In these cases diagnosis may be difficult, and the result may be fatal if operation does not give relief. Bronchitis occurs in rare instances, and especially when there has been an attack just previous to the anæsthetization. Pneumonia occurs in a varying proportion of cases. Its relation to the anæsthesia is not exactly determined (*vide* p. 102). According to Van Beck, the use of ether in Czerny's clinic has been restricted because of its injurious effects upon the respiratory tract. The occurrence of pneumonia after anæsthesia may easily be overlooked, as there is frequently absence of chill, and slight or irregular rise in temperature. The physical signs are also apt to be atypical. Most of the cases occur during cold weather, and the change from a warm operating room to a cold corridor may have its causative effect. Again, a deep and prolonged narcosis may tend to favor the occurrence of pneumonia. The pneumonia usually appears within the first 24 hours succeeding the administration of the anæsthetic.

The lung complications after anæsthesia which were formerly

thought to occur only after ether or chloroform are known to occur after any form of anæsthesia, even after local anæsthesia. The statistics of Chevers and Ericksen show that these complications were much more frequent in pre-antiseptic days than at present. Aufrecht found that lung complications followed the use of chloroform, but not as frequently as they did the use of ether. Mikulicz (German Congress of Surgery, 1901) gave 1,007 laparotomies and operations for goitre under general anæsthesia, with 7.5 per cent. of pneumonia and a mortality of 3.4 per cent. Also 273 laparotomies (local anæsthesia), with 12.8 per cent. of pneumonia, and a mortality of 4.8 per cent. Operations on the neck, mouth, jaws, and chest also seem to favor the development of pneumonia. Mikulicz is inclined toward general anæsthesia in these cases, and favors chloroform unless there is some contra-indication to its use. Ether is more dangerous because it is more irritating to the respiratory passages and because it increases the secretion of mucus.

Regarding the ætiology of lung complications after operation, the conclusions of Geralanos may be accepted. The irritant action of the agent on the respiratory tract and the hypersecretion (ether); the toxic effect of the agent on the blood vessels, resulting in hyperæmia, œdema of the lungs, secondary heart effects, due to both chloroform and ether, especially the latter. This condition favors hypostatic pneumonia, diminishes local resistance to infection which may occur by inspiration, infected emboli, or by bacteria in the blood; the inspiration of infected material from secretions of the mouth and pharynx, or vomitus; infected or non-infected emboli from thromboid vessels (usually veins) from the region of operation; chilling, fright or shock from the operation, with or without hæmorrhage, all lower resistance. Prolonged narcosis, exposure of the chest or peritoneal cavity reduce temperature; general weakness of the patient lowers resistance; interference with respiration and expectoration by pain or wound or by tight bandages.

Acute œdema of lungs, according to Lindemann, occurs from toxic dilation of the blood vessels and hyperæmia of the lung tissue.

Embolic pneumonia is independent of the general narcosis and is due to the nature of the operation and of the disease. In

strangulated hernia and ileus of other forms the mesenteric veins may be thrombosed beyond the seat of the constriction even though the bowel be not gangrenous. When the constriction is removed emboli may form and pass to the lungs. The emboli may be infected; or, if not, the infarct produced may become infected from organisms already in the bronchi, or from the blood. Emboli may form in any operation when there is thrombosis either before or after operation. They are most common in connection with laparotomies, may be secondary to phlebitis of the lower extremities, which sometimes occurs after laparotomies.

Gangrene and abscess of the lungs are rare after operation. They are due to inspiration of infected material, or to infected emboli.

In weak, debilitated subjects the dressings should be loose, the patient should be encouraged to inspire deeply and to expectorate, the mouth and pharynx should be kept clean, especially if the patient vomits. If there is much pain small doses of morphine are advisable. Abdominal distention should be prevented. The position of the patient should be changed frequently, and the head and shoulders should be slightly raised.

Various paralyses may occur from pressure incident to certain operations. They are usually transient in character. Leszynsky believes that paralysis is due to lesion of the nerve trunk and is a peripheral paralysis from pressure, extension, elevation, unnecessary position, etc. Flatau thinks that in anæmia and in arteriosclerosis cases the paralysis is central. Bloodgood noted five instances of paralysis of the upper extremities in about five hundred operations. In each case the pectoral muscles had been divided, allowing of greater extension of the extremity than usual. The precautions to be taken are obvious and are important, as the recovery may be tedious.

Anuria after anæsthesia is considered by some observers due to the effect of large doses of the agent in modifying the flow of blood through the kidneys. Exposure of the patient's body, and reflex disturbance from operations on the genito-urinary tract are also considered factors producing anuria. The therapeutic indications are: Strychnia and digitalis if the circulation is depressed; normal salt solution per rectum or under the skin;

and nitroglycerine if sclerotic conditions of the vessels indicate the possible presence of vascular spasm.

The special after-effects of the individual anæsthetics have been mentioned under their respective causes and need not be repeated here.

PART II.

Local Anæsthesia and Anæsthetics.

CHAPTER XV.

LOCAL ANÆSTHESIA.

The local employment of anæsthetic substances or mixtures, or of cold in the form of ice or freezing mixtures, as well as constriction of the parts, has long been practised for anæsthetic purposes. Little was accomplished in this direction, however, until Richardson introduced the hand-ball spray method of using ether for the purpose of local anæsthesia. This method consists in directing an atomized current of ether against the part to be operated on. The rapid evaporation of the ether produces an intense degree of cold which freezes the part. The chief objections to this method are the pain caused by its application to sensitive tissues, and the burning sensation which follows resumption of function by the nerves and vessels of the part. The ether used for this purpose should have a sp. gr. not to exceed 0.723.

Rhigolene, the lightest liquid known, is more effective than ether, but is difficult to handle because of its great volatility. It is a product of the fractional distillation of petroleum.

These agents have had but a limited application for minor surgical operations. Since the introduction of cocaine, however, as a local anæsthetic agent the field for this method of anæsthesia has enlarged until at present, with the exception of certain operations on the organs and cavities of the body, most of the major operations come within the possibilities of local anæsthesia. There can be no question but that general anæsthesia is very frequently used where local anæsthesia would answer. This is specially true in regard to short operations when the dangers of general anæsthesia, and its post-operative complications, might be largely avoided by the employment of local anæsthesia, particularly as in the last few years the technique, effectiveness, and applicability of local anæsthesia has been immensely improved.

In regard to prolonged operations involving considerable shock, the most recent observations show that the expectation that local anæsthesia would prove less dangerous than general anæsthesia is not warranted. While local anæsthesia is possible in this class of operations, shock is just as severe or more so under local

as under general anæsthesia, and post-operative complications appear to be about as frequent and as fatal.

The frequency and fatality of post-operative pneumonia and other lung complications in connection with operations on the stomach and intestines by local anæsthesia is greater, according to the statistics of Mikulicz, than after general anæsthesia. The shock, fright, and unpleasant conditions arising from the conscious state of the patient renders these prolonged, tedious operations very trying under local anæsthesia.

These conditions, together with the difficulty of obtaining complete muscular relaxation in some cases, militates against local anæsthesia in this class of operations, unless it could be proven that both primary and secondary dangers were practically obviated.

In relation to the selection of methods, Mikulicz says that the question now is in which class of cases shall general narcosis be substituted for local anæsthesia; that in one group of cases the indications for local anæsthesia are absolute. In this group should be included all operations which can properly be performed under local anæsthesia, whether a general anæsthetic is contraindicated or not, such as minor operations, tracheotomy, gastrostomy, etc. In another group is placed those operations in which there is yet doubt as to the safer method of anæsthesia, such as major operations on the stomach and intestines, free and strangulated hernia, goitre, etc.

For reasons already mentioned most surgeons place operations on the organs within the abdomen as unsuitable for local anæsthesia. Bloodgood places reducible hernia in the doubtful group because of the difficulty of completing the operation in some cases under local anæsthesia, and thinks that in patients where a general anæsthesia is contraindicated, the operation should be performed under local anæsthesia or not at all. Strangulated hernia he places under the group indicating local anæsthesia.

In operations for goitre the special dangers of general anæsthesia, and the success of such operators as Kocher with local anæsthesia, influence many surgeons to include operations for struma in the group indicating local anæsthesia.

COCAINE.

Cocaine ($C_{17}\ H_{20}\ NO_4$) is an alkaloid obtained from the

erythroxylon coca, N. O. Linaceæ. The name coca is derived from the Aymara (Indian) word *khoka,* signifying "plant" (or tree, i. e., the specially favored one). The plant grows to a height of six or eight feet, has bright green leaves, and bears small, white flowers. It resembles the blackthorn. The natives of Peru and neighboring provinces cultivate the shrub. The Spanish found the natives of Peru familiar with the narcotic properties of the plant. The leaves were dried in the sun, and mixed with a little lime to form a preparation for chewing, something like the betel leaf of the East. Under its stimulus the natives were able to perform tasks requiring great endurance. Prescott says, "Even food the most invigorating is less grateful to him than his loved narcotic." According to Clusius, the Indians stated that while using coca neither hunger or thirst annoyed them, while their strength and vigor were maintained.

The use of coca did not become general until after Pizarro ravaged the country. Previous to this time, during the reign of Tupac Inca Yupangin, the most renowned of the "children of the sun," and of his son, Huayno Copac, during whose reign Vasco Nunez de Balboa took possession of the new continent from a "peak of Darien", in the name of Ferdinand and Isabella, and up to the time of the overthrow of Atohuallpa, the plant was reserved for the use of the Incas, the coca plantations or "cocals" being owned by the state.

The continued use of coca forms a habit similar to the opium habit. Appetite is lost, digestion weakened, and an inordinate desire for animal food follows. Then follow boils, dropsical swellings, fœtid breath, pale lips, discolored teeth, dim, sunken eyes, yellow, discolored skin, and the *coquero* becomes as pitiable an object as the most confirmed opium habitué.

The effects of coca depend on the presence of the alkaloid *cocaine,* which has basic properties and combines with acids to form salts. It crystallizes in prisms which are transparent and colorless when pure. It is slightly soluble in water, and in alcohol, and freely soluble in ether. It has a bitter taste, and its salts are more bitter than the alkaloid itself. Coca contains, beside the alkaloid, an aromatic oil "hygrine", discovered by Lossen in 1862, which has an alkaline reaction and a biting taste, but is with-

out therapeutic virtue. Coca is slightly astringent from the presence of a tannic acid.

Cocaine was discovered by Gordeke in 1855, and called *erythroxyline.* It was afterward named *cocaine* by Niemann, who first studied carefully its physiological action.

Cocaine hydrochlorate occurs in colorless, transparent crystals, or as a white, crystalline powder, without odor, with a slightly bitter taste, and produces on the tongue a tingling sensation followed by a numbness. It is soluble at 59° F. (15°C.) in 0.48 parts of water, and in 3.5 parts of alcohol.

The local anæsthetic action of cocaine when applied to the skin, mucous membranes, wounds, or ulcerating surfaces, became known soon after its discovery in 1855, and was noted by Morenoy and Maiz, in 1862, and by von Aurep in 1883. Koller, of Vienna, demonstrated its value, especially in ophthalmic practice, in 1884, and Noyes, of New York, who observed his demonstrations, published them in this country.

Locally applied, cocaine produces anæsthesia, and a condition of anæmia due to contraction of the arterioles. Solutions do not affect the intact skin. Personal idiosyncrasy markedly affects the action of cocaine. Alarming depression has followed the use of a few drops of a 4 or 6 per cent. solution in the eye, or in the nasal passages, or the use of as little as one-eighth of a grain hypodermically, and death has followed moderate doses. It is not actively toxic, and some persons can take large doses without ill effects.

The experiments of Crile, of Cleveland, show that in animals under the effects of cocaine or eucaine exposure or manipulation of the intestines, mechanical irritation of sensitive tissues, manipulation of the larynx, stimulation of the vagi, operations on the larynx and other portions of the body produced little or none of the fall of blood pressure which characterized such procedures in the control animals. The vessels of the splanchnic area are smaller and much less congested in the cocainized animals.

The effects of cocaine on the circulation were, first, a rise in blood pressure, followed by a fall; and later a gradual rise. The inhibitory action of the vagus is partially or wholly suspended. The vaso-motor reflexes are lessened. The circulation is less responsive to stimulation.

A small dose acts as a stimulant to the respiration; a medium dose diminishes the length of the respiratory stroke; large doses cause gradual diminution of the respiration. Some degree of tolerance is acquired by successive doses, and general anæsthesia is more difficult to induce in animals under the influence of these drugs.

In ophthalmological practice anæsthesia is first induced in the conjunctiva and cornea, and may be produced by 2 per cent. solutions, though 5 per cent. solutions act quicker, and are suitable for the deeper structures. Prolonged contact, wounds, or incisions aid the diffusion of the anæsthetic. Simple congestion does not materially hinder the action of the anæsthetic, though chronic changes retard its effects. Where such changes are present, or when operative procedures have recently preceded the use of the anæsthetic, its action may be aided by the preliminary use of a solution of adrenalin.

Some mydriasis occurs from the action of cocaine, reaches its maximum in about one hour, and disappears in from two to three hours. The pupil remains sensitive to light (Koller). Accommodation is moderately affected.

In the surgery of the naso-pharynx, larynx, urethra, bladder, etc., solutions of from 4 to 6 per cent. are necessary, and dangerous conditions are therefore more likely to arise. More caution is being exhibited in its use in these connections, and eucaine b. is being much substituted for cocaine, as being less toxic, while equally anæsthetic.

Crile emphasizes the importance of the local application of cocaine solution to the larynx or pharynx (2 per cent.), along with the hypodermic use of atropine to prevent reflex inhibition of the heart and respiration.

Legrand recommends a mixture of cocaine and ethyl chloride, which is used as a spray. In five minutes the ethyl chloride is evaporated and leaves the cocaine on the surface as a whitish deposit. It is useful in making painful applications to ulcerating surfaces, or to skin lesions.

Local Infiltration Method.—This method of producing local anæsthesia by infiltrating the skin with an anæsthetic solution was introduced by Halsted and Hall, who experimented in this direction in 1884 and 1885. Schleich, for whom this method is

usually named, and who fully developed the method, published his first results about four years later. Liebrich, Halsted, and Schleich have shown that an artificial œdema of the tissues, especially of the papillary layer of the skin, produces slight anæsthesia, but not analgesia. Halsted (1885) found it possible to completely anæsthetize the skin to any extent by subcutaneous injection of water, and employed this process for minor operations. This anæsthesia did not extend beyond the boundary of the weal, and did not always disappear as hyperæmia appeared. Halsted found normal salt solution less painful than water.

Schleich demonstrated the possibility of perfect and painless anæsthesia by infiltration with weak solutions of cocaine (0.1 per cent. or less). Success depends on the proper infiltration of the skin, and other tissues as they are dealt with. Extensive operations and dissections may be performed by this method because of the dilute nature of the solutions and the freedom with which they may be used without danger of toxic effects.

Most authorities advise a 0.1 per cent. solution, or less, of cocaine for infiltration. Some think that morphine is not necessary for the success of the anæsthesia, and for extensive operations omit the morphine and dilute with sterile salt solution as the operation proceeds. The solutions should be sterilized by repeated heating in a water bath, or in a steam sterilizer (fractional method). Matas drops the tablet prepared by manufacturers into boiled water, and heats the solution nearly to the boiling point two or three times. This is a simple and practical method. Many authorities state that boiling injures the anæsthetic qualities of cocaine solutions, but when carefully sterilized there appears to be no injury to their properties.

Technique.—The success of the infiltration depends on the proper production of a weal. The first injection is somewhat painful, and a fine needle should be used. It should be introduced in a slightly oblique direction, and the fluid injected into the skin, and not beneath it, so as to produce an elevation of the epidermis, which becomes white from anæmia. The first weal should be large. The needle may be thrust beneath the skin, injecting the fluid as it proceeds, or it can be withdrawn and introduced just within the border of the weal so as to cause no pain, and a succession of weals produced of sufficient extent for the necessary in-

cisions. If several syringes are at hand the infiltration can be made rapidly. It is sometimes of advantage to further œdematize the area by injections of sterile salt solution. As the nerve trunk, filaments, and the vessels of the deeper tissues are also painful, it is necessary, in deep operations, to œdematize the deeper tissues by infiltrating them in the same manner. Experienced operators know just what tissues to infiltrate. If one is not sure it is best to infiltrate the tissues before dividing them.

Combined with other methods next to be considered, extensive operations are possible that could not be performed by this method alone. Tearing or traction of the tissues causes more pain than to cut them.

Diminished resistance of infiltrated tissues, infection, suppuration, necrosis, and imperfect healing of wounds so infiltrated are not to be feared if proper precautions are taken. If the tissues about vessels are infiltrated before dividing the vessels, hæmostasis can be obtained. Pain from suturing of wounds can be prevented by reinfiltration from the margin of the skin incisions.

Regional Paraneural Infiltration.—This method was introduced by Halsted, Hall, and Corning, in 1884 and 1885. It was extensively used by Oberst, and is generally known by his name. It consists in infiltration of the tissues about the peripheral nerves supplying the part to be operated on, and above the point of operation. It was first used for operations about the fingers and toes, but as the technique improved has been extended to operations on the entire extremities, and for areas of the head, neck and trunk.

Technique.—An Esmarch, elastic constriction bandage is placed upon the toes, foot, ankle, leg, thigh, fingers, wrist, forearm, or arm, as the case may be, a short distance above the seat of the operation. Corning was the first to employ the Esmarch bandage in connection with this method of anæsthesia. It was first used to allow of the deep injection of stronger solutions or larger amounts than is ordinarily used, and which are sometimes necessary with this method. There is less danger of toxic effects when the constriction is used, and when the bandage is left on for from one-half to one hour the injection appears to lose its toxic effects, according to some observers, because of some action of the tissues upon the drug. Some authorities claim that the Es-

march bandage is unnecessary, but the majority believe in its good effect.

Walsendorf, in 1676, produced anæsthesia by simple constriction of the limb, and Esmarch states that he performed painless operations on the fingers and toes by means of constriction.

The application of the bandage is rather painful, which is less if the constriction is just sufficient to occlude the vessels, and a broad band is used. The deep injection is made just below the bandage, and the tissues about the nerve are infiltrated. The number of injections will depend on the number of nerves to be anæsthetized. The region supplied by these nerves becomes anæsthetic in from five to ten minutes, and the anæsthesia lasts long enough for operative procedures. The bandage should be left on for one-half hour or more if strong solutions have been used. If weak solutions have been injected the bandage may be removed at once. The weaker solutions are adapted to the combined use of this method with direct injection of the nerve, and local infiltration of the skin. The bandage may here be discarded, or may be removed as soon as the operation is completed.

The Regional Intraneural Method.—By this method the nerve trunk is exposed by the infiltration method, and then injected with a 0.5 to 1 per cent. solution of cocaine. Cushing's method was to inject the nerve as it was exposed during the dissection. He perfected his method especially for hernia operations. When this method is properly performed all afferent impulses are checked. The method was suggested by Crile and Matas particularly for amputations and operations on the extremities.

According to Bieberfield, cocaine is necessary in this method, and solutions of from 0.25 to 0.5 per cent. are advisable.

Crile has performed major amputations with this method, and says the technique is based on the fact that "nerve trunks may be safely and effectually subjected to a physiologic 'block' by injecting cocaine or eucaine in a comparatively weak solution, and that arteries may be, with entire safety, temporarily closed without injury to their walls." He exposes the nerve trunks under local anæsthesia and injects their sheath and then their substance with a 0.5 per cent. solution of cocaine, just sufficient to cause a localized swelling. Shock is almost wholly avoided because all afferent

impulses are blocked, shock being due to afferent impulses, occasioned by operation or injury. General anæsthesia only slightly modifies these afferent impulses, abolishing those for pain, but not controlling those for the vaso-motor, respiratory, or cardiac mechanism. Cocaine or eucaine absolutely blocks afferent impulses and wholly prevent reflex inhibition, as in operations about the larynx or pharynx. Hypodermically they diminish shock in operations about the splanchnic area, and diminish the effects of operation on or exposure of this area.

The preliminary use of a hypodermic dose of morphine of from one-eighth to one-fourth of a grain before local anæsthesia by any method is recommended.

Bagot produces local anæsthesia by a mixture of cocaine and spartein sulphate. The latter is used to counteract the depressing effect of cocaine. He uses powders, each containing three-fifths of a grain of cocaine and three-fourths of a grain of spartein, and dissolves one powder in 15 drops of boiling water, and another in 30 drops of boiling water. Fifteen drops of the weaker solution are injected in the part to be operated on, and in 7 or 8 minutes the remaining fifteen drops are injected. The wound is touched, from time to time, with the stronger solution.

OTHER LOCAL ANÆSTHETIC AGENTS.

Eucaine a, or Alpha eucaine (C_{19} H_{27} NO_4).—Forms glossy prisms melting at 104° C. Because of the insolubility of the base the hydrochloride is usually employed. Eucaine hydrochloride is soluble in the proportion of 1 in 10 parts of water. It has local anæsthetic properties like cocaine. It is not decomposed by heat during sterilization. It was supposed to have less action on the heart than cocaine, but has been practically discarded because of its general toxic properties, which resemble those of strychnia poisoning. In ophthalmic practice it produces considerable pain and burning, and because of this is sometimes combined with cocaine (cocaine hydrochloride, eucaine hydrochloride, aa. 0.05 gm., aqua., 5 gm.). As a nose and throat application a 5 to 10 per cent. solution may be used.

Eucaine B, or Beta eucaine (C_{15} H_{21} NO_2 HCL). — The hydrochloride of benzoyl—vinyl—diacetonalkamin, used as a substitute for cocaine. The crystals are soluble in water and are not

decomposing on heating. It melts at 263° C. (505.4° F.) It is completely free from irritating properties, is less toxic than cocaine, and is said to be 3.75 times less toxic than eucaine a.

Eucaine b. was introduced by Silex in 1897. It is the most satisfactory substitute for cocaine as yet obtainable. It is not equal to cocaine in its anæsthetic qualities, but is distinctly less toxic. When large amounts of weak solutions are required, eucaine b. is recommended by many. For the urethra and bladder it can be used in 4 per cent. solutions to considerable amounts, and is employed in preference to cocaine. About the nose and throat it is safer than cocaine. In Oberst's paraneural infiltration, and for operations high up on the extremities, it may be used in stronger solutions than cocaine with safety. For intraneural injections a solution of 1 per cent. may be used extensively, which might be troublesome with cocaine. In ophthalmic practice eucaine b. is not as satisfactory as cocaine. Schleich believes that if operations can be performed with 0.1 per cent. or less of cocaine, it is the better agent, and that if toxic symptoms appear during the operation eucaine b. should be substituted. Reclus says the advantages of eucaine b. are: It can be sterilized by boiling; the solution is stable; it is much less toxic than cocaine. He makes the patient lie down after using a 1 per cent. solution of cocaine, which is unnecessary when eucaine b. is used.

Heinzle says eucaine b. is the best agent. The solutions should be used at the body temperature. He employs 1 part of eucaine b., 8 parts of sodium chloride, and 100 parts of distilled water.

Eucaine b. is used in sterilized solutions up to 2 per cent. The anæsthesia may be in some instances as complete as that of cocaine, and more rapid, but does not last so long. It is less irritant and toxic than cocaine. There is often a decided burning sensation for an hour or so after its use.

TROPA-COCAINE HYDROCHLORIDE (bensoyl-pseudo-tropein) is an alkaloid derived from the small-leaved coca plant of Java. It was first isolated by Giesel, and is identified with the pseudotropein of hyoscyamus by Liebermann, who prepared it synthetically. It occurs as white needles, melting at 271°C. (519.8° F.), and is readily soluble in water. According to Ferdinande and Chadbourne a 2 or 3 per cent. solution produces more rapid, re-

liable and less toxic anæsthesia than cocaine. Tropa-cocaine was also advocated by Curtis.

HOLOCAIN.—Obtained by uniting molecular quantities of phenacetine and para-phenetidin with separation of water. It forms insoluble crystals, melting at 121° C. The hydrochloride is usually employed; this forms bitter-tasting crystals, soluble in cold water to the extent of 2½ per cent. It has been used in ophthalmology as a substitute for cocaine. Two or three drops of a 1 per cent. solution is generally sufficient to produce anæsthesia in from 15 seconds to 10 minutes. Most ophthalmologists regard it as much inferior to cocaine. Pouchet rejects holocaïn because of want of uniformity in its action.

NIRVANIN.—This synthetical product is chemically related to orthoform. It appears as white prisms, which are fully soluble in water, melt at 185°, and give a violet color with ferric chloride. A 5 per cent. solution instilled into the eye causes complete anæsthesia after temporary irritation of the conjunctiva. Upon less sensitive mucous membranes the solution is not irritating, but does not produce such complete anæsthesia. Used subcutaneously, the effect is complete and prolonged. It is used subcutaneously in from 2 to 5 per cent. solutions. It is said to be less toxic than orthoform, and according to Luxenburger is only one-tenth as toxic as cocaine. Elsberg states that nirvanin is three times less toxic than eucaine. Nirvanin is a stable compound, and may be boiled without deterioration. Compared with cocaine, Floeckinger states, nirvanin is less toxic, is anti-bactericidal, its anæsthetic effects are more prompt and prolonged, there is less danger of drug habit, and after pain is absent when the injection is properly performed. Other authorities are not so favorably impressed with nirvanin. Diedrichson regards it as not altogether harmless.

The following formula is recommended for use on mucous membranes, or for subcutaneous injections:

℞

Nirvanin	gr. ij (gm 0.13)
Sodii chloridi	gr. i (gm 0.06)
Aqua destil. (sterile)	f. ʒij (gm 8.00)
M.	

According to Matas, nirvanin and eucaine b. are the only agents that deserve to be classed as succedanea of cocaine. Be-

cause of their lesser toxicity, their stability under sterilization, and for other reasons they may be used with advantage along or in conjunction with cocaine, and while not superseding cocaine, they have contributed to the widening field of local anæsthesia.

ORTHOFORM.—This synthetic compound occurs as a white, voluminous, odorless, and tasteless powder. It is permanent, and non-hygroscopic, very slightly soluble in water, and soluble in ether. By some it is said to be non-toxic, but untoward effects have been observed by Wunderlich, Katz, and others. According to Luxenberger, orthoform is compatible with iodoform, dematol urophen, aristol, calomel, salicylic acid, carbolic acid, lysol, lead-water, boric acid, alumen acetate, ichthyol, turpentine, iodine, and copper sulphate. Chemical changes occur in connection with bismuth subnitrate, potassium permanganate, and silver nitrate. Precipitation occurs when orthoform is combined with bichloride of mercury, or formaldehyde. Antipyrine triturated with orthoform is converted into a semi-liquid. Orthoform hydrochloride forms a soluble, crystalline salt, and though anæsthetic is not adapted to subcutaneous injection.

Owing to its insolubility orthoform is not adapted to subcutaneous use, though it may be so used suspended in oil. Its insolubility minimizes the danger of toxic effects. It has little effect on the intact skin, though a lanolin ointment if well rubbed in will relieve skin irritations. Applied to open wounds or ulcerations, as a dusting powder, or in a 10 or 20 per cent. ointment, anæsthesia follows and lasts for two or three hours.

The chief use of orthoform is to relieve painful lesions of the surface of the body, or of the mucous membranes, to relieve the pain of cancer, to relieve painful cystitis when used by irrigation, in painful conditions of the ear, eye, larynx, etc. In gastralgia and painful stomach disorders it may be used in doses of from 7½ to 15 grains (0.50 to 1 gm.) Dreyfus uses orthoform to powder wounds made under the Schleich infiltration method of anæsthesia.

According to Cheatham the results obtained with orthoform at the Munich surgical clinic are as follows: 1. Loss of sensation occurs on the average in from 3 to 5 minutes after application, whether as a powder or as a 10 per cent. or 20 per cent. ointment. 2. The anæsthetic action continues on the average for about 30

hours, in many cases even for 3 or 4 days. 3. Diminution of secretion is always observed, a valuable feature in transplantations, or in inoperable cancer of the face. 4. Two ounces weekly, applied to a carcinoma, demonstrated its non-toxic nature. 5. Antiseptic properties were not demonstrated, though purulent discharges ceased after its application.

Aneson.—This is a trade name for a watery solution of acetone-chloroform, which has sufficient anæsthetic power for some operations, though it is not equal to a 5 per cent. solution of cocaine. It has been used in ophthalmology, nasal, laryngeal, dental, and minor surgery, in 1 or 2 per cent. solutions. The solution is colorless, does not affect the iris or irritate the eyes. It causes no ill effects when injected in quantities of several Pravaz syringefuls. It is recommended by Mosbacher as a substitute for cocaine because it is always sterile, is less toxic, and causes no after pains. Sternberge says it is non-toxic and non-irritant, and produces anæsthesia quicker than cocaine.

Ethyl Chloride.—Ether chloratus, chlor-ethyl, monochlorethane ($C_2 H_5 Cl$), also called chelen or kelene. Produced by the action of dry hydrochloric acid gas on absolute alcohol. At ordinary temperature it constitutes a gas which is easily condensed to a liquid, boiling at 10° C (50° F.). Because of the intense cold (about 35° C.) produced by its evaporation, it is used as a local anæsthetic. For this purpose it is obtained commercially in small hermetically sealed tubes (Fig. 53), terminated by a capillary point. When used this point is broken off and the tube held in the hand, the warmth of the hand being sufficient to expel the liquid through the small opening in a stream which is directed on the surface which it is desired to anæsthetize. Ethyl chloride occasions considerable pain, especially to sensitive tissues. It is adapted for small surgical or dental operations, and has been

Fig. 53.—Ethyl Chloride Tube.

Fig. 53. Ethyl chloride is, as a rule, contained in small tubes or cylinders constructed either of glass or metal and provided with screw caps. Each of these contains a sufficient quantity of the agent for from ten to fifteen minor surgical operations.

used somewhat for therapeutic purposes. Ethyl chloride is inflammable and should not be used near an open flame.

Liquid Air.—As a local anæsthetic for minor operations liquid air is recommended by Campbell, also as a cauterizing agent in various local conditions. The reaction from the freezing occurs in about 20 minutes and is attended by marked hyperæmia. According to MacFayden and S. Roland, after the exposure of various bacteria to a temperature of —190° C for a period of seven days in liquid air, no alteration was observed in their structure, and there was no change observed in their virulence except that they grew a trifle more slowly. According to White, the repeated application of liquid air serves as an antiseptic through inhibiting bacterial action. He recommends it as a local anæsthetic which causes only slight tingling, the only precaution being to freeze the part solid.

The spray gives relief in intestinal and trifacial neuralgia, and in sciatica. Boils, buboes, and carbuncles may be aborted in their early stages if thoroughly frozen, and specific, chancroidal, and varicose ulcers heal promptly if treated twice a week by freezing.

CHAPTER XVI.

LOCAL ANÆSTHETICS IN DENTISTRY.

It is probably true that there is no subject of more interest to the dental profession than that of anæsthesia. Most of the operations upon the teeth, jaws and adjacent parts are painful to a greater or less degree. The dentist's immediate field of operation is supplied by the branches of the fifth pair of nerves, perhaps the most sensitive of any in the human body, and especially is this true regarding pain, which is the only sensation conveyed by the tooth pulp. Add to this the fact that patients usually present themselves in a high state of nervous excitement, due to fearful anticipations, a condition in which a slight hurt is magnified in the pain centers so that the consequent effect upon the strength and nervous make-up of the patient is often very serious.

People do not like to be hurt, and are seeking painless operations. It is also true that the majority of operators can render better service when they know they are not hurting their patients. A rule, then, that I would like to lay down is: When work can be done successfully, painlessly, without seriously endangering the health of the patient, it is advisable.

Any agent that has for its object the relief of pain is worthy of our careful study. Most strictly dental procedures come under the head of *minor* operations. General anæsthetics can only be used in serious, prolonged dental operations, such as removal of tumors, cancers, necrosis, reduction of fractures, cleft-palate, hare-lip, the extraction of a large number of teeth, and the like.

The objections to their use for dental purposes are:

1. The difficulty of keeping the patient under during operations on the mouth.

2. The necessary recumbent position often seriously interferes with the operator and makes difficult the flushing of the wound without much blood, pus or other debris being swallowed.

3. Dangers to life or health from the anæsthetic. We are not justified in using such an agent except where very necessary.

4. After sickness, vomiting often endangers the success of operations.

The reader is referred to the chapter on general anæsthet-

ics for a full discussion of the subject, including methods of administering. The only special requirement for dental purposes is a carefully fitted mouth prop.

Nitrous oxide gas is very largely used by the dental profession, and, indeed, very satisfactorily in those cases for which it is adapted. The transitory nature of the anæsthesia limits its usefulness to very short operations. The Hurd and other similar methods, by which a certain amount of air or oxygen is mixed with the gas, have a larger range of usefulness. The advantage being that anæsthesia can safely be prolonged from five to fifteen minutes, but even with this it cannot be used in many operations on the teeth themselves because of the need of dryness and aseptic conditions that are so essential to success. However, wherever nitrous oxide can be used, it is perhaps our safest agent, its one objection being the necessity of rendering the patient unconscious.

The subject of local anæsthetics has elicited more experimentation and discussion on the part of the dental profession than any other subject in recent years. At first their use was given over to the quack, but gradually the demand for their employment became so great that a few daring ones took up the subject and tried to study out the best method of using them with greatest success and least danger to the patient, until to-day I feel safe in saying that these agents are used in one way or another by a vast majority of the profession.

First come the use of so-called freezing mixtures, made up principally of ethyl bromide, ethyl chloride, rhigolene, and other light petroleum ethers which hold in solution various agents. They are usually kept in a small glass tube with such thin walls that the heat of the hand will expand the contents so as to cause a fine spray to rush from the end of the tube, where a valve is placed which can be opened. The method of using is to direct this spray on the mucous membrane on and around the field of operation until blanching of the part appears. Care must be had not to use too long, or destruction of the soft tissue will result. They are fairly useful for small operations, such as lancing abscesses.

Many use for this same purpose solutions containing carbolic acid, menthol, calabar bean, peppermint in sulphuric ether, and apply with a pledget of cotton with, I think, some satisfaction.

The greatest success from local anæsthetics comes from the use

of agents which are employed in various per cent. solutions by means of hypodermic injection directly into the soft tissue. Among such agents I only wish to mention three, viz., cocaine hydrochlorate, beta-eucaine hydrochlorate, and chloretone. The first has been used longest and has been, in the hands of the writer, most successful.

For the general physiological action of these drugs the reader is referred to the chapter on local anæsthetics. I simply wish to mention here the results of many hundred experiments with cocaine and eucaine conducted on dogs, guinea pigs and rabbits, as well as in a clinical practice extending over a period of twelve years. At the outset, I want it understood that my statements only apply to operations in the mouth where injections are made through the mucous membrane,—for I recognize that the nature of the tissue into which injections are made, has much to do with results. My conclusions are as follows:

1. Cocaine is more toxic than beta-eucaine.
2. Cocaine is more anæsthetic than beta-eucaine.
3. Cocaine is more rapid in its action.
4. Cocaine solutions are more irritating to tissue.
5. Cocaine is less dangerous in its action upon the heart.
6. Cocaine is not constant in its effects—you cannot tell who will be most susceptible.
7. Beta-eucaine acts almost always the same on different individuals.
8. Cocaine solutions will not keep long and cannot be boiled, while beta-eucaine solutions can be sterilized by boiling and are fairly stable.
9. When danger symptoms arise from cocaine administration, they are more easily counteracteed than when they arise from beta-eucaine.
10. Cocaine local effects are more lasting than beta-eucaine.

Many dentists report cases of severe local irritant poisoning from cocaine hydrochlorate, but from my observations I would say this is due to an impure drug, unclean syringe, or infection from some source.

I do not wish to convey the idea that cocaine is not a dangerous drug when used in dental practice, but I wish to affirm that if properly used in reasonable physiological quantities, in correct

solution, its dangers are not great, and its local anæsthetic effects almost ideal. The same can be said of beta-eucaine, but in my hands the greatest success, everything considered, has been obtained from use of cocaine.

Of all the agents recommended to counteract the baneful systemic effects of cocaine, I find none to equal nitroglycerin, although caffein, coffee, morphine, atropine and strychnine are recommended and are of value. The trouble with them is they are comparatively slow in action, and therefore should be given fifteen to thirty minutes before cocaine is administered. When trouble arises it is like sending a horse to catch the lightning express, but nitroglycerin acts more rapidly and can be given in the cocaine solution with good results. Cocaine acts best for dental injections when used in a 1 per cent. solution, with nitroglycerin added. I find that if the solution is made in sterilized peppermint water with just a trace of thymol it will keep nicely and seems to be slightly more anæsthetic. Beta-eucaine is used in a 2 per cent. aqueous solution and can be boiled.

Chloretone is a comparatively new agent recommended for local anæsthetic purposes. It is quite harmless and can be used in almost unlimited quantities. It is not soluble to exceed 1 per cent. in water, which is the solution recommended. The writer has had but negative results from use of this agent, although many claim splendid success with it.

A very important point to be remembered is the value of mechanically filling the tissue with the solution used. When you succeed in raising up a small white button with each injection you can feel assured of success. The method of using these agents for the extraction of useless teeth and roots is as follows:

1. Have your cocaine or eucaine in perfect solution.

2. Have solution sterile or antiseptic.

3. Have your syringe aseptic. I like to use an all metal one which can be boiled. It should have a large finger guard and plunger rest and be arranged so as to tell exactly how much is given.

4. Have all air out of the syringe.

5. Always clean the surface through which you wish to inject.

6. Make your injection into the dense gum tissue first; then deep into the periosteum on all sides of the tooth to be extracted.

7. Wait until effect takes place before beginning to operate.

8. Have additional means at hand to meet dangerous symptoms should they arise.

9. Do not use more than one-sixth of a grain of cocaine, or one-third of a grain of eucaine at one time.

The combination of cocaine and chloretone seems to promise good results. The chloretone seems to counteract the dangerous effects of cocaine on the heart and respiration. Suprarenal extract in connection with cocaine solution is very useful for operations on soft tissues of the mouth.

Orthoform.—A local anæsthetic in the form of a light gray powder. It is very sparingly soluble, and hence its use is limited to those cases where the powder can be applied direct. It is very useful in painful alveolar sockets after teeth are extracted. There is no danger of poisoning because it dissolves so slowly that little enters the circulation at one time.

Cocaine is used in painful pus pockets to anæsthetize the surrounding tissue, thereby making possible the scaling of teeth with little pain. It is used in a 4 per cent. solution injected by means of a long platinum needle directly into the pockets. Care should be taken to pack absorbent cotton around the tooth to absorb any escaping excess, thus avoiding getting it back in the throat.

A 1 per cent. solution is injected in the gum around a tooth to render painless the preparation of sensitive cavities for filling, also into the gum to relieve the pain of putting on clamps to hold the dam in place; especially is this useful when the gum has to be forced down on the tooth to get the dam over the margin of cavities.

Cocaine and eucaine are both employed to relieve pain of excavating sensitive cavities and to anæsthetize the tooth pulp so it can be removed immediately. The process now mostly used for this last purpose is to place the dam, remove the superficial decay, outline the cavity, then moisten a small pledget of cotton with water or alcohol or ether and touch this to the finely powdered cocaine or beta-eucaine, when sufficient will adhere; place this in the cavity and take a piece of soft rubber larger than the cavity and with a blunt instrument gently force the cocaine into

the tooth with a sort of pumping motion—renew your agent from time to time and get a complete exposure of the pulp as soon as possible, when little difficulty will be experienced in completely anæsthetizing the pulp so it can be removed painlessly.

The objections to this method are:

1. When pulps are congested it only works partially.
2. The time taken to do it painlessly.
3. The hæmorrhage following.

In many cases it is advisable to use it, and as a general practice it is growing in favor.

The same method is employed for sensitive dentine except that no exposure is made.

There was a time a few years ago when the profession went wild over the use of cocaine by means of the cataphoric apparatus, which is a machine so arranged to measure and control electric current as to be able to pass a small amount through the cavity in a tooth. It is used in connection with cocaine as above described—the positive electrode is placed on the cotton in the cavity and the negative electrode on the cheek or held in the hand. This method is now practically abandoned in favor of the others mentioned.

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